Vol. 39, No. 6 December, 1949

Journal of Experimental Psychology

EDITED BY

FRANCIS W. IRWIN

UNIVERSITY OF PENNSYLVANIA

CONSULTING EDITORS

CLARENCE H. GRAHAM, *Columbia University*
HARRY HELSON, *Brooklyn College*
DONALD B. LINDSLEY, *Northwestern University*
DONALD G. MARQUIS, *University of Michigan*
GEORGE A. MILLER, *Harvard University*
L. L. THURSTONE, *University of Chicago*
G. R. WENDT, *University of Rochester*
JOSEPH ZUBIN, *N. Y. Psychiatric Institute, Columbia University*

CONTENTS

The Role of Fear in the Motivation and Acquisition of Responses: J. S. BROWN AND A. JACOBS 747
The Acquisition of a Black-White Discrimination Habit under Two Levels of Reinforcement: B. REYNOLDS 760
Acquired Distinctiveness of Cues: I. Transfer between Discriminations on the Basis of Familiarity with the Stimulus: D. H. LAWRENCE 770
Selective Association and the Anticipatory Goal Response Mechanism as Explanatory Concepts in Learning Theory: A. AMSEL 785
Spatial Learning in the T-Maze: The Influence of Direction, Turn, and Food Location: H. C. BLODGETT, K. MCCUTCHAN, AND RAVENNA MATHEWS 800
Studies in Learning and Motivation: I. Equal Reinforcements in Both End-Boxes, Followed by Shock in One End-Box: E. C. TOLMAN AND H. GLEITMAN 810
Attitudinal Determinants of Conditioning and of Generalization of Conditioning: G. RAZRAN 820
The Formation and Retention of Remote Associations in Rote Learning: J. T. WILSON 830
The Perception of the Vertical: III. The Visual Vertical as a Function of Centrifugal and Gravitational Forces: C. E. NOBLE 839
Learning Function for a Change in the Scale of Judgment: D. M. JOHNSON 851
On the Application of Analysis of Variance to GSR Data: III. Some Effects of the Use of Inappropriate Measures: E. A. HAGGARD 861
Conditioned Generalization of the Galvanic Skin Reaction to Tones: R. A. LITTMAN 868
Reactive Inhibition as a Factor in Maze Learning: III. The Role of Reactive Inhibition in Studies of Place Learning versus Response Learning: M. E. THOMPSON AND JEAN P. THOMPSON 883
Discussion: Comments on Littman's "Conditioned Generalization of the Galvanic Skin Reaction to Tones": C. I. HOVLAND, 892. *Some Observations on Meyer's Study of Reaction Time and Muscle Tension:* R. S. DANIEL, 896. *Some Remarks concerning Daniel's Observations:* H. D. MEYER, 898.

PUBLISHED BI-MONTHLY BY
THE AMERICAN PSYCHOLOGICAL ASSOCIATION, INC.
PRINCE AND LEMON STS., LANCASTER, PA.
AND 1515 MASSACHUSETTS AVE., N. W., WASHINGTON 5, D. C.

Entered as second-class matter, February 6, 1937, at the post office at Lancaster, Pa., under the Act of March 3, 1879
Acceptance for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph 4, Section 538, P. L. & R., authorized September 11, 1947.

JOURNAL OF EXPERIMENTAL PSYCHOLOGY

The JOURNAL OF EXPERIMENTAL PSYCHOLOGY is published bi-monthly by the American Psychological Association, Inc. The annual subscription rate is $7.00 (foreign, $7.50); single copies, $1.25. Subscriptions, orders, and business communications should be addressed to the American Psychological Association, Inc., 1515 Massachusetts Ave., N.W., Washington 5, D. C.

This JOURNAL publishes articles which are intended to contribute toward the development of psychology as an experimental science. Experimental work with normal human subjects is favored over work with abnormal or animal subjects. Articles of a length exceeding 25 printed pages cannot be accepted.

With rare exceptions, articles are published in the order of their receipt. Authors are supplied with 50 free offprints, without covers, in the case of articles of seven or more printed pages, and with five free copies of the issue in the case of shorter contributions. One-half of the cost of tables, cuts, formulas, and author's alterations in galley proof is charged to the author.

Immediate publication can be given to articles whose authors assume the full cost of publication.

Address articles submitted for publication to the editor, Francis W. Irwin, Department of Psychology, University of Pennsylvania, Philadelphia 4, Pa.

This JOURNAL adheres to the conventions concerning bibliographies, citations, preparation of tables and cuts, etc., as described by J. E. ANDERSON and W. L. VALENTINE, The preparation of articles for publication in the journals of the American Psychological Association, *Psychol. Bull.*, 1944, **41**, 345–376. Special attention is called to the style of numbers and abbreviations (p. 353). The term 'experimenter,' with its various forms, singular, plural, and possessive singular and plural, is abbreviated *E*, *E*s, *E*'s, and *E*s'; analogous abbreviations are used for the terms 'subject' (*S*) and 'observer' (*O*). All manuscripts should be typed double-spaced throughout, *including tables, footnotes, and bibliography*. Tables, figures, and footnotes should be placed on separate pages at the end of the manuscript.

Journal of Experimental Psychology

EDITED BY

FRANCIS W. IRWIN

UNIVERSITY OF PENNSYLVANIA

CONSULTING EDITORS

CLARENCE H. GRAHAM, *Columbia University*
HARRY HELSON, *Brooklyn College*
DONALD B. LINDSLEY, *Northwestern University*
DONALD G. MARQUIS, *University of Michigan*
GEORGE A. MILLER, *Harvard University*
L. L. THURSTONE, *University of Chicago*
G. R. WENDT, *University of Rochester*
JOSEPH ZUBIN, *N. Y. Psychiatric Institute, Columbia University*

Volume 39, 1949

PUBLISHED BI-MONTHLY

BY THE AMERICAN PSYCHOLOGICAL ASSOCIATION, INC.

PRINCE AND LEMON STS., LANCASTER, PA.

AND 1515 MASSACHUSETTS AVE., N. W., WASHINGTON 5, D. C.

Entered as second-class matter, February 6, 1937, at the post office at Lancaster, Pa., under the Act of March 3, 1879
Acceptance for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph 4, Section 538, P. L. & R., authorized September 11, 1947.

LANCASTER PRESS, INC., LANCASTER, PA.

CONTENTS OF VOLUME XXXIX

AMSEL, A. **Selective Association and the Anticipatory Goal Response Mechanism as Explanatory Concepts in Learning Theory** 785

BLACK, J. W. **Loudness of Speaking: The Effect of Heard Stimuli on Spoken Responses** 311

BLODGETT, H. C., MCCUTCHAN, K., AND MATHEWS, RAVENNA. **Spatial Learning in the T-Maze: The Influence of Direction, Turn, and Food Location** 800

BLOOMBERG, R., AND WEBB, W. B. **Various Degrees within a Single Drive as Cues for Spatial Response Learning in the White Rat** 628

BROWN, J. S., AND JACOBS, A. **The Role of Fear in the Motivation and Acquisition of Responses** 747

BROWN, J. S., AND SLATER-HAMMEL, A. T. **Discrete Movements in the Horizontal Plane as a Function of Their Length and Direction** 84

BUXTON, C. E. **Repetition of Two Basic Experiments on Reminiscence in Serial Verbal Learning** 676

BUXTON, C. E., AND BAKAN, MILDRED B. **Correction vs. Non-Correction Learning Techniques as Related to Reminiscence in Serial Anticipation Learning** 338

BUXTON, C. E., AND ROSS, H. V. **Relationship between Reminiscence and Type of Learning Technique in Serial Anticipation Learning** 41

CAMERON, N., AND MAGARET, ANN. **Experimental Studies in Thinking: I. Scattered Speech in the Responses of Normal Subjects to Incomplete Sentences** 617

CHAPANIS, A., ROUSE, R. O., AND SCHACHTER, S. **The Effect of Inter-Sensory Stimulation on Dark Adaptation and Night Vision** 425

CHERNIKOFF, R., AND BROGDEN, W. J. **The Effect of Instructions upon Sensory Pre-Conditioning of Human Subjects** 200

CLARK, B., AND MACCORQUODALE, K. **The Effects of Repeated Rotary Acceleration on the Oculo-Gyral Illusion** 219

COOK, BARBARA S., AND HILGARD, E. R. **Distributed Practice in Motor Learning: Progressively Increasing and Decreasing Rests** 169

CRUTCHFIELD, R. S., AND EDWARDS, W. **The Effect of a Fixated Figure on Autokinetic Movement** 561

DANIEL, R. S. **Some Observations on Meyer's Study of Reaction Time and Muscle Tension** 896

DAVIS, R. C., AND VAN LIERE, D. W. **Adaptation of the Muscular Tension Response to Gunfire** 114

DIXON, J. C. **Concept Formation and Emergence of Contradictory Relations** 144

DOUGHTY, J. M. **The Effect of Psychophysical Method and Context on Pitch and Loudness Functions** 729

ESTES, W. K. **A Study of Motivating Conditions Necessary for Secondary Reinforcement** 306

FILER, R. J., AND MEALS, D. W. **The Effect of Motivating Conditions on the Estimation of Time** 327

GAGNÉ, R. M., AND FOSTER, HARRIET. **Transfer of Training from Practice on Components in a Motor Skill** 47

GAGNÉ, R. M., AND FOSTER, HARRIET. **Transfer to a Motor Skill from Practice on a Pictured Representation** 342

GEBHARD, MILDRED E. **Changes in the Attractiveness of Activities: The Effect of Expectation Preceding Performance** 404

GEBHARD, MILDRED E. **Permanence of Experimentally Induced Changes in the Attractiveness of Activities** 708

GILINSKY, ALBERTA S. **Relative Self-Estimate and the Level of Aspiration** 256

GLIXMAN, A. F. **Recall of Completed and Incompleted Activities under Varying Degrees of Stress** 281

GRANT, D. A., HORNSETH, J. P., AND HAKE, H. W. **Sensitization of the Beta-Response as a Function of the Wavelength of the Stimulus** 195

GRANT, D. A., JONES, O. R., AND TALLANTIS, BILLIE. **The Relative Difficulty of the Number, Form, and Color Concepts of a Weigl-Type Problem** 552
GRANT, D. A., AND MOTE, F. A. **Effects of Brief Flashes of Light upon the Course of Dark Adaptation** 610
GRANT, D. A., AND SCHNEIDER, DOROTHY E. **Intensity of the Conditioned Stimulus and Strength of Conditioning: II. The Conditioned Galvanic Skin Response to an Auditory Stimulus** 35
GUILFORD, J. P., AND HOLLEY, J. W. **A Factorial Approach to the Analysis of Variances in Esthetic Judgments** 208
GWINN, G. T. **The Effects of Punishment on Acts Motivated by Fear** 260
HAGGARD, E. A. **On the Application of Analysis of Variance to GSR Data: I. The Selection of an Appropriate Measure** 378
HAGGARD, E. A. **On the Application of Analysis of Variance to GSR Data: III. Some Effects of the Use of Inappropriate Measures** 861
HANES, R. M. **A Scale of Subjective Brightness** 438
HANES, R. M. **The Construction of Subjective Brightness Scales from Fractionation Data: A Validation** 719
HARRIS, J. D., AND MYERS, C. K. **The Emergence of a Tonal Sensation** 228
HILGARD, E. R., DUTTON, C. E., AND HELMICK, J. S. **Attempted Pupillary Conditioning at Four Stimulus Intervals** 683
HOROWITZ, M. W. **An Analysis of the Superiority of Binocular over Monocular Visual Acuity** 581
HOVLAND, C. I. **Experimental Studies in Rote-Learning Theory: VIII. Distributed Practice of Paired Associates with Varying Rates of Presentation** 714
HOVLAND, C. I. **Comments on Littman's "Conditioned Generalization of the Galvanic Skin Reaction to Tones"** 892
IRION, A. L. **Reminiscence in Pursuit-Rotor Learning as a Function of Rest and of Amount of Pre-Rest Practice** 492
IRION, A. L. **Retention and Warming-Up Effects in Paired-Associate Learning** 669
JENKINS, W. O., and CUNNINGHAM, LETA M. **The Guessing-Sequence Hypothesis, The 'Spread of Effect,' and Number-Guessing Habits** 158
JENKINS, W. O., AND POSTMAN, L. **An Experimental Analysis of Set in Rote Learning: Retroactive Inhibition as a Function of Changing Set** 69
JOHNSON, D. M. **Generalization of a Reference Scale for Judging Pitch** 316
JOHNSON, D. M. **Learning Function for a Change in the Scale of Judgment** 851
JOHNSON, E. P. **The Electrical Response of the Human Retina During Dark-Adaptation** 597
KIENTZLE, MARY J. **Ability Patterns under Distributed Practice** 532
KIMBLE, G. A. **An Experimental Test of a Two-Factor Theory of Inhibition** 15
KIMBLE, G. A. **A Further Analysis of the Variables in Cyclical Motor Learning** 332
KIMBLE, G. A. **Performance and Reminiscence in Motor Learning as a Function of the Degree of Distribution of Practice** 500
KIMBLE, G. A., AND BILODEAU, E. A. **Work and Rest as Variables in Cyclical Motor Learning** 150
LACEY, O. L., AND SIEGEL, P. S. **An Analysis of the Unit of Measurement of the Galvanic Skin Response** 122
LAMBERT, W. W., SOLOMON, R. L., AND WATSON, P. D. **Reinforcement and Extinction as Factors in Size Estimation** 637
LAWRENCE, D. H. **Acquired Distinctiveness of Cues: I. Transfer Between Discriminations on the Basis of Familiarity with the Stimulus** 770
LEYZOREK, M. **Accuracy of Visual Interpolation between Circular Scale Markers as a Function of the Separation between Markers** 270
LITTMAN, R. A. **Conditioned Generalization of the Galvanic Skin Reaction to Tones** 868
MANN, C. W., BERTHELOT-BERRY, N. H., AND DAUTERIVE, H. J., JR. **The Perception of the Vertical: I. Visual and Non-Labyrinthine Cues** 538
MCCLELLAND, D. C., CLARK, R. A., ROBY, B. T., AND ATKINSON, J. W. **The Projective Expression of Needs. IV. The Effect of the Need for Achievement on Thematic Apperception** 242
MEYER, H. D. **Reaction Time as Related to Tensions in Muscles not Essential in the Reaction** 96

MEYER, H. D. **Some Remarks concerning Daniel's Observations** 898
NOBLE, C. E. **The Perception of the Vertical. III. The Visual Vertical as a Function of Centrifugal and Gravitational Forces** 839
NUTTIN, J. **'Spread' in Recalling Failure and Success** 690
PASSEY, G. E., AND GUEDRY, F. E., JR. **The Perception of the Vertical: II. Adaptation Effects in Four Planes** 700
POSTMAN, L., AND BRUNER, J. S. **Multiplicity of Set as a Determinant of Perceptual Behavior** 369
PRENTICE, W. C. H. **Continuity in Human Learning** 187
RAZRAN, G. **Semantic and Phonetographic Generalization of Salivary Conditioning to Verbal Stimuli** 642
RAZRAN, G. **Attitudinal Determinants of Conditioning and Generalization of Conditioning** 820
REED, J. D. **A Note on Reaction Time as a Test of Color Discrimination** 118
REYNOLDS, B. **The Relationship between the Strength of a Habit and the Degree of Drive Present during Acquisition** 296
REYNOLDS, B. **The Acquisition of a Black-White Discrimination Habit Under Two Levels of Reinforcement** 760
RIGGS, L. A., AND JOHNSON, E. P. **Electrical Responses of the Human Retina** 415
ROHRER, J. H. **Factors Influencing the Occurrence of Reminiscence: Attempted Formal Rehearsal during the Interpolated Period** 484
SENDERS, VIRGINIA L. **Visual Resolution with Periodically Interrupted Light** 453
SEWARD, J. P. **An Experimental Analysis of Latent Learning** 177
SEWARD, J. P., AND LEVY, N. **Sign Learning as a Factor in Extinction** 660
SHEFFIELD, F. D. **'Spread of Effect' without Reward or Learning** 575
SHEFFIELD, VIRGINIA F. **Extinction as a Function of Partial Reinforcement and Distribution of Practice** 511
SHIPLEY, W. C., NANN, BARBARA M., AND PENFIELD, MARY JANE. **The Apparent Length of Tilted Lines** 548
SMITH, F. L., SWEET, A. L., AND BARTLETT, N. R. **The Discrimination of Small Differences in the Time of Mechanical Stimulation** 561
SMITH, K. R., AND WEVER, E. G. **The Problem of Stimulation Deafness. III. The Functional and Histological Effects of a High-Frequency Stimulus** 238
SMITH, M. H., JR. **Spread of Effect Is the Spurious Result of Non-Random Response Tendencies** 355
SMITH, S. **A Further Reduction of Sensory Factors in Stereoscopic Depth Perception** 393
SOLOMON, R. L. **The Role of Effort in the Performance of a Distance Discrimination** 73
SOLOMON, R. L. **A Note on the Alternation of Guesses** 322
THOMPSON, M. E., AND THOMPSON, JEAN P. **Reactive Inhibition as a Factor in Maze Learning: III. The Role of Reactive Inhibition in Studies of Place Learning versus Responsive Learning** 883
THORNDIKE, E. L. **New Data on the Influence of Frequency and of Mind Set** 395
TINKER, M. A. **Involuntary Blink Rate and Illumination Intensity in Visual Work** .. 558
TOLMAN, E. C., AND GLEITMAN, H. **Studies in Spatial Learning: VII. Place and Response Learning under Different Degrees of Motivation** 653
TOLMAN, E. C., AND GLEITMAN, H. **Studies in Learning and Motivation. I. Equal Reinforcements in Both End-Boxes, Followed by Shock in One End-Box** 810
UNDERWOOD, B. J. **Proactive Inhibition as a Function of Time and Degree of Prior Learning** 24
WEBB, W. B. **The Motivational Aspect of an Irrelevant Drive in the Behavior of the White Rat** 1
WENZEL, BERNICE M. **Differential Sensitivity in Olfaction** 129
WILSON, J. T. **The Formation and Retention of Remote Associations in Rote Learning** 830
WITHEY, S., BUXTON, C. E., AND ELKIN, A. **Control of Rest Interval Activities in Experiments on Reminiscence in Serial Verbal Learning** 173
WRIGHT, SUSAN T. H., AND TAYLOR, D. W. **Distributed Practice in Verbal Learning and the Maturation Hypothesis** 527
ZEAMAN, D. **Response Latency as a Function of the Amount of Reinforcement** 466

Journal of
Experimental Psychology

VOL. 39, NO. 6 DECEMBER, 1949

THE ROLE OF FEAR IN THE MOTIVATION AND ACQUISITION OF RESPONSES[1]

BY JUDSON S. BROWN AND ALFRED JACOBS

State University of Iowa

An important concept in a number of current theories of behavior is that the emotion of fear is (usually) a learned, anticipatory response to painful stimulation and that its significance as a behavior-determinant lies primarily in its motivational properties. The assumption that fear is a learned response stems from the fact that it can be elicited by (conditioned) stimuli which in the past have been closely associated with, or have been followed by, noxious (unconditioned) stimuli. The additional assumption that fear is (or produces) a drive, rests on the assertion that it exhibits certain of the major functional properties commonly attributed to primary drives such as hunger. Specifically, (1) the presence of fear is said to energize or motivate behavior, and (2) a reduction in fear is said to act as a reinforcement for the acquisition of new responses. Since the fear reaction is learned, the resulting drive is termed secondary or acquired to distinguish it from primary drives whose antecedent conditions are unlike those typically observed in learning situations.

This conception, which is essentially a translation of certain Freudian (4) ideas into stimulus-response terms, was first proposed by Mowrer (9). Subsequently, he and others have applied the notion to the interpretation of a variety of behavior and have carried out a number of experiments tending to support the hypothesis (3, 6, 8, 11, 12). A recent study by N. E. Miller (7), which apparently provides the most convincing confirmatory evidence, forms the point of departure for the present investigation.

The procedure employed by Miller may be summarized briefly as follows. The apparatus consisted of an oblong box, divided by a sliding door into two compartments, one white with a grid floor, the other black with a smooth floor. During preliminary training trials, rats were allowed to escape a shock in the white compartment by running into the black, the door being open. On subsequent learning trials, the animals were placed in the white

[1] The second of the two experiments reported herein has been previously described in a paper presented by the second author at the 1948 meeting of the Midwestern Psychological Association. The authors are indebted to Dr. I. E. Farber for a careful reading of the manuscript and for numerous stimulating suggestions made during the course of the experiments.

side with the door closed, but with no shock on the grid. If an animal made the 'correct' response of turning a small wheel (located over the door) within 100 sec., the door dropped and the rat could escape into the black compartment. If the response was not made within the allotted time, the animal was lifted out of the box to await its next trial. The results obtained on the learning trials indicated clearly that if the wheel-turning response occurred a few times early in the series it was then rapidly learned, apparently being reinforced by the reduction in fear accompanying escape into the black compartment. Thirteen out of 25 animals showed clear-cut evidence of learning the new response. On subsequent trials, when the wheel-turning response was made 'incorrect' for these 13 rats, it extinguished rapidly, and a new 'correct' response of pressing a bar to open the door was readily learned. Since no shock was administered on any of the learning trials, the results were interpreted as indicating that the fear aroused by the stimuli from the white compartment provided a drive which led to random activity and hence to the initial correct responses, and that the reduction in fear accompanying escape from the white box operated to reinforce the wheel-turning and bar-pressing responses.

Although Miller's interpretation of his results in terms of fear and its reduction appears quite plausible, there are other interpretations that merit consideration. One alternative is to assume that frustration, not fear, is the important drive in the situation and hence that frustration-reduction is the significant reinforcing event. According to this hypothesis, the interruption or blocking of any strong, on-going response produces a state of frustration or anger which functions as a drive. In Miller's experiment, the response which was blocked was that of running from the white box into the black, a response which had been powerfully reinforced by shock-reduction during the training trials. On the learning trials, when this response was prevented from occurring by the closed door, the hypothetical frustration drive might well have been aroused. This drive, like that of fear, could lead to the appearance of varied activity and, eventually, to the correct response of turning the wheel. Since the opening of the door would permit the resumption of the running response, there would follow an almost immediate reduction in frustration. As a consequence, the tendency to perform the wheel-turning response would be strengthened by this decrease in drive.

The two experiments reported herein were designed to control for this possible frustration factor by eliminating the locomotor response from the initial training situation. The general procedure employed in both studies involved a number of training trials during which rats were placed in an oblong box and given paired presentations of a neutral (conditioned) stimulus and an electric shock. On subsequent learning trials, the conditioned stimulus was presented without shock and an opportunity was provided for the animals to execute a new response of crossing from one side of the box to the other by jumping over a barrier. If the barrier-crossing response occurred, the conditioned stimulus was immediately terminated. Learning was estimated from the latencies of the barrier-crossing responses. In the case of both experiments it was assumed that: (1) the pairing of the neutral stimulus and the shock would result in the development of a condi-

tioned fear response; (2) the presence of fear would lead to varied responses, including that of crossing the barrier; and (3) the barrier-jumping reaction would be reinforced by the cessation of the conditioned stimulus and the consequent reduction in fear. It was also assumed that, since no specific escape response was reinforced by shock-reduction during training, the possibility of arousing frustration during the subsequent learning trials would be negligible. The two experiments differed with respect to certain details such as number of training trials, nature of the conditioned stimulus, and so on. These variations led to certain differences in the results which are believed to be of importance for interpretations of fear-motivated behavior.

Experiment I

Apparatus.—The apparatus consisted of an oblong box 14 in. long, 5 in. wide, and 5 in. deep (inside dimensions), painted flat black and provided with a grid floor. The grid was constructed of $\frac{3}{32}$-in. brass rods, spaced at intervals of $\frac{1}{8}$ in. The lid of the box was constructed by tacking celluloid to a light wooden frame hinged to the upper edge of the box. A removable barrier extended two in. above the grid floor when in position.

The shocking current was obtained from a 75,000-ohm potentiometer wired as a voltage divider across the 500-volt secondary of a conventional radio power transformer. The voltage was applied to the grid through a fixed resistor of 0.3 megohm. The shock-voltage values given below represent readings from a 2000-ohm-per-volt a.c. voltmeter connected across the output leads of the potentiometer at all times.

The conditioned stimulus was the sound produced by a high-frequency buzzer (Speedex Type) operating on six volts a.c. The latencies of the barrier-crossing responses were measured with a stop-watch from the onset of the conditioned stimulus until an animal had crossed completely over the barrier.

The room was in almost complete darkness save for the illumination provided by a 10-watt lamp suspended about 18 in. directly above the center of the box.

Subjects.—Two groups of 10 rats, each consisting of eight hooded females and two albino males approximately 100 days old, were used as *Ss*. Within each sex the animals were assigned to the two groups at random.

Training Procedure.—The procedure followed during training was designed to produce a conditioned fear response in the animals of the experimental group, but not in those of the control group. Each animal of the fear group was placed in the apparatus (with barrier absent) and given 40 paired presentations of buzzer and shock, 10 per day for four successive days. The buzzer was sounded for either 2, 3, or 4 sec. before the shock and continued to sound with the shock for either 3, 4, or 5 sec. Individual trials were spaced at intervals of either 4, 5, or 6 min. The durations of buzzer, buzzer with shock, and inter-trial interval were selected at random from the above ranges and the same sequence was administered to all animals. At the conclusion of each day's training, each animal was left in the apparatus for 10 min. before being returned to its home cage. The shocks were 160 volts for the females and 180–200 volts for the larger males. Food and water were present at all times in the home cages. The animals in the control group were trained in exactly the same manner as were those in the experimental group, except that *no shocks were given the controls at any time.*

Testing Procedure.—The two-in. barrier was introduced into the center of the box and each animal was given 40 learning trials, 10 on each of four successive days. On each learning trial, an animal was placed in the box and the buzzer was sounded *but no shock was presented.* When the rat jumped the hurdle, the buzzer was immediately turned off. On the first day, successive trials were given at five-min. intervals. If a response had not occurred by the end of a continuous three-min. sounding of the buzzer, the buzzer was turned off and two min. were allowed to pass before the next trial. On Days 2, 3, and 4, the trials were run at four-min. intervals, the buzzer being turned off when the response was completed, or after an interval of two min. if no response occurred. The initial trial of the first day was given five min. after an animal was placed in the box; on the other days the interval preceding the first trial was three min. As in the case of the training procedure, the animals were returned to their cages 10 min. after the last trial of a day. The control and experimental animals were treated in an identical manner throughout the learning session.

Results.—The outcome of the procedure followed in Experiment I is

TABLE I

MEAN LOG LATENCIES (PLUS 1.0) FOR SUCCESSIVE BLOCKS OF FIVE LEARNING TRIALS

	Trials							
	1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40
Control Group	2.23	2.64	2.40	2.52	2.26	2.47	2.30	2.40
Exper. Group	2.75	2.54	2.28	2.29	2.01	2.04	1.81	1.95

summarized in Table I where the mean log latencies (plus a constant of 1.0) for successive blocks of five learning trials have been listed for both the experimental and the control groups. These values have also been plotted in Fig. 1. The individual response latencies (in sec.) were transformed into logarithms in order to normalize the data for statistical treatment. The constant was added so that the values obtained here could be plotted to the same scale as those in the second experiment where a constant was added to avoid negative logarithms.

An examination of these statistics shows that the experimental animals exhibited a progressive decrease in the latency of the barrier-crossing response with successive non-shock trials. All but one of the experimental animals learned the new response with a fair degree of prompt-

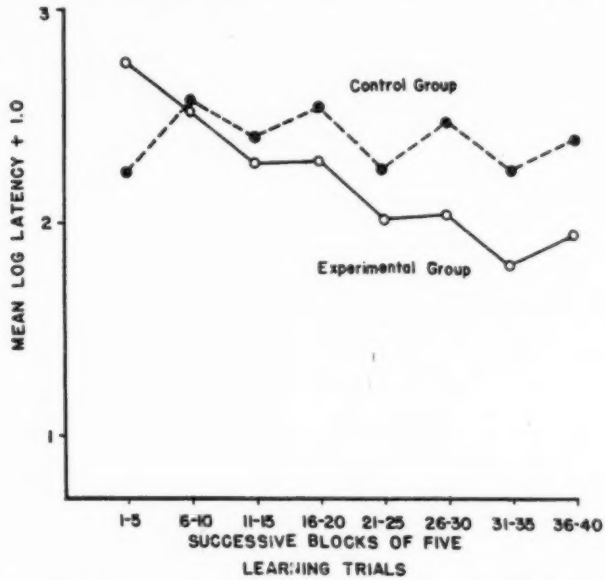


FIG. 1. Latencies of barrier-crossing responses made by the experimental and control animals on successive blocks of five learning trials. The experimental animals were presumably fearful and show evidence of improved performance with fear-reduction as the reinforcement for the new response. The non-fearful controls show no improvement. These curves were plotted from the values listed in Table I.

ness. The one that did not learn made only one barrier-crossing response during the 40 test trials. The scores for this animal have not been included in the treatment of the data. That the decrease in latency shown by the group as a whole can scarcely be attributed to chance is indicated by the highly significant value of t obtained from a comparison of the means of the first and the last five trials of this group. This t-value is the first shown in Table II. By comparison, the control animals (not shocked during training) showed no progressive decrease in latency during the course of the learning trials. In fact, their mean reaction latency on trials 36–40 was longer than that on trials 1–5, although the difference is not significant, as may be seen from the second entry in Table II.

It is important to note, however, that although the fear-group animals showed clear evidence of learning the new response and were significantly faster than the controls on the last five trials (fourth entry, Table II), they were significantly slower than the controls on the first five trials (third entry in Table II). As a result of this reversal in the relative proficiences of the two groups, a statistical comparison of the *overall means* of the two groups does not lead to the rejection of the null hypothesis (last value in Table II).

One feature of the data that is of interest is the cyclic fluctuations in latency exhibited by both the control and experimental animals (Fig. 1). In the case of the controls, the mean latencies were longer on the last five trials of each day than on the first five. This suggests that exploratory tendencies were undergoing extinction during the course of each day's trials. Consistent with this interpretation is the fact that the controls also had shorter latencies on the first five trials of each of the last three days than on the last five trials of each preceding day. Conceivably, this reflects the spontaneous recovery of the extinguished exploratory tendencies.

The cyclic fluctuations shown by the experimental animals were limited to the last three days of testing (trials 11–40) and were less marked than those of the controls. These might also be attributed to the extinction and spontaneous recovery of exploratory behavior on the assumption that the exploratory tendencies were superimposed upon the gradually developing tendency to cross the barrier in response to the buzzer. It is quite possible, however, that processes of extinction and spontaneous recovery were actually taking place in the case of either the jumping response or the fear response, or both.

Discussion.—The major objective of the present study was to determine whether the rewarding and energizing functions commonly attributed to

TABLE II

A Summary of Tests of Significance Computed Between Various Means for Both Experimental and Control Animals

Trials or Groups Compared	t	d.f.	P
1. Trials 1–5 vs. 36–40 (Exper.)	5.70	8	$<.01$
2. Trials 1–5 v. 36–40 (Cont.)	2.00	9	$<.10, >.05$
3. Exper. vs. Cont.: Trials 1–5	4.40	17	$<.01$
4. Exper. vs. Cont.: Trials 36–40	2.97	17	$<.01$
5. Exper. vs. Cont.: Mean of all trials	1.55	17	$<.20, >.10$

fear, but also ascribable in special cases to a drive resulting from the frustration of a locomotor response, would be exhibited under conditions unfavorable to the development of frustration. Since, in this experiment, clear evidence of learning was obtained under such conditions, it may be concluded that the *rewarding function* of fear-reduction receives additional experimental support, and that frustration, at least of the hypothesized variety, is apparently not an essential element.

It has been shown that the cessation of a normally neutral stimulus, after that stimulus has been repeatedly presented with a noxious one, acquires the property of strengthening new stimulus-response connections. In accounting for this empirical fact, it may be assumed that the pairing of the two stimuli results in the neutral one's becoming a conditioned stimulus which evokes a fear reaction. This reaction, which may be a fractional anticipatory component of the unconditioned response to the noxious stimulus, is presumed, perhaps by virtue of the stimulation it provides (8), to add an increment to the general drive level of the animal. As a consequence, any new reaction occurring in close temporal proximity to the cessation of the fear response and the consequent drive reduction will be reinforced.

With respect to the *energizing function* of fear, it must be concluded that the present experiment yields no direct evidence that fear leads inevitably to an increase in random or exploratory movements. If such were the case, one would anticipate that the *initial* barrier-crossing responses of the fearful (experimental) animals would have been quicker than those of the controls, since on the first few trials, before any appreciable learning had occurred, the response latencies should reflect rather directly the tendency to make random movements. This expectation is not confirmed by the data. On the first trial, for example, the fearful animals were much slower than the controls, the mean log latencies for the two groups being 2.71 and 1.88 sec., respectively. And even at the end of the first five trials when the mean latency for the controls had risen to 2.23 sec. (five trials combined) the fearful group was still significantly inferior to the controls.

From qualitative observations of the behavior of our animals it seems probable that the initial response latencies of the experimental rats were long because these animals were more prone to 'freeze' or crouch than were the non-fearful ones. In some instances, the fearful rats were fairly active when first placed into the apparatus but would immediately become immobile when the buzzer was sounded. It seems likely, therefore, that under the conditions of this study, fear was quite often accompanied by a reduction in random activity instead of by an increase in activity. Confirmatory evidence for these observations is provided by Miller (7), who reports marked crouching on the part of some of his animals, and by Arnold (1), who states categorically (though on the basis of only two or three studies) that fear is always accompanied by a reduction in somatic activity.

Although these findings appear to be inconsistent with the hypothesis that fear exhibits the energizing function of a drive, the hypothesis may be retained, provided one abandons the rather limited assumption that drives, when functioning as energizers, always lead to more vigor-

ous overt or random action.[2] Thus, it may be supposed, as Hull (5) does, that the generalized drive state (D), to which all of the specific drives or needs contribute, combines in a multiplicative manner with the habit values of both learned and innate responses ($_{S}H_{R}$'s and $_{S}U_{R}$'s). Other things equal, the response which occurs is that having the strongest habit, irrespective of the specific drives which are the major contributors to the strength of D. If crouching is exhibited instead of random activity, then the strength of the crouching habit must be greater than that for random action, and the stronger the drive, the more intense the crouching will be. According to this conception, then, *the presence of fear may act as an energizer (by virtue of its contribution to D) and yet lead in certain instances to an increase in immobility.*

The question remains, of course, as to why the habit of crouching should be strong for fearful animals but not for non-fearful ones, or for ones highly motivated by hunger, thirst, etc. One answer, suggested by Miller (7), is that crouching occupies a dominant position in the hierarchy of innate responses to the stimuli accompanying (or arising from) fear. Hungry animals do not crouch because hunger-produced stimuli are different from fear-produced stimuli and are not innately associated with responses of immobility.

[2] It should be noted that although both Mowrer and Miller have, in general, restricted their treatments of the energizing function of fear to its role as a motivator of so-called random or trial-and-error behavior, neither of them has apparently held the view that random activity is the only variety of response that will be exhibited when the drive of fear is present. Such a view, however, of the energizing action of drives is rather commonly expressed in introductory treatments of motivation (see, e.g., Shaffer, 13, p. 89).

It is also possible that crouching is *learned* during the shock trials, and that it becomes conditioned to the fear stimuli, as well as to stimuli provided by the shock and the apparatus. Crouching or freezing would certainly be reinforced if they occurred at the time the shock was turned off or if they led in some way to either a complete or partial reduction of shock.[3] Although no systematic observations were made of such behavior, the impression is strong that the initial reactions of the animals to shock were almost always ones of rather violent action. Immobility reactions never became dominant until after a number of shock trials had been administered. Similar observations of the learning of immobile reactions to escape shock have been made by Mowrer (10). We would conclude tentatively, therefore, that responses of crouching or standing still may well have been acquired during the course of the training trials in our experiment, and that in all probability these responses were conditioned to both external and internal stimuli by the reinforcing effect of reductions in shock intensity.[4]

[3] A reduction in shock intensity would result if an animal's position led to an increase in contact area and a decrease in current density through the tissues of its feet. Or, complete elimination of shock could be effected by an animal's standing on its hind feet and touching only one side of the shock circuit. When such postures were adopted in this experiment, it was noted that marked increases could be produced in the shock voltage without disturbing the animals. This constitutes objective evidence that the animals were not feeling the shock at those times. On a few occasions it was even necessary to move an animal forcibly into a new position in the apparatus so that further shock trials could be given.

[4] It seems highly probable that, if crouching can be learned as a reaction to fear, animals could also be trained to be exceptionally active in the presence of fear by suitably reinforcing such activity. Confirmatory evidence for this

Although in this experiment the evidence for learning appears to be relatively unambiguous, since the fearful animals were significantly superior to the controls when compared on the last five trials, it is possible that some of the drop in the curve of Fig. 1 for the fear group could have been due to factors other than learning. In particular, the initial fall of the curve, at least to the point where it crosses the control-group curve, might indicate merely that the freezing responses were becoming extinguished and that the level of general activity was increasing. An increase in activity level would be quite likely to lead to shorter response latencies. Thus it was felt that the interpretation of at least the first segment of the curve was difficult and that further experimentation was needed.

Experiment II

Purpose.—The second experiment was conducted to determine whether by modifying the procedure of the first, the degree of freezing exhibited by the fearful rats could be substantially reduced while maintaining fear at a sufficiently high level to enable it to serve in a reinforcing capacity. The changes in procedure were designed to reduce the opportunities for the animals to learn to crouch, and to make conditions more favorable for the learning of the new response. Specifically, the procedure of the second experiment when compared with that of the first involved (1) a reduction in the number of shock trials, (2) a change from steady shock to pulsating shock, (3) a change in the conditioned stimulus, (4) a modification of the learning procedure, making it unnecessary for the animals to shuttle back and forth in the apparatus, and (5) the introduction of an irrelevant (hunger) drive.

Apparatus.—The same basic apparatus described above was used. The box was modified to permit the introduction of a guillotine-type door which extended down through the top at the center and rested directly on the upper edge of the two-in. partition. This served to divide the box into two compartments of equal size and appearance.

Because of noticeable fluctuations in both the frequency and intensity of the buzzer used in Experiment I and because of its somewhat raucous sound, a new conditioned stimulus was introduced. This consisted of a light and tone presented together, both being interrupted 100 times per min. by a commutator on a small synchronous motor. The light was provided by an inside-frosted 10-watt lamp suspended 12 in. above the exact center of the box. The tone, generated by a resistance-capacitance oscillator and fed directly into a five-in. permanent magnet speaker, had a frequency of 2000 cycles and an intensity, measured at the top of the box, of about 70 db. above a reference level of 10^{-16} watts/cm.^{2} This compound stimulus of pulsating light and tone was employed in order to achieve distinctiveness without at the same time increasing intensity to the painful or slightly noxious level. The shock was the same as in Experiment I, except that the circuit was interrupted at the same rate as were the light and tone. This modification was introduced because exploratory work revealed that with intermittent shock there was apparently less chance that the animals would adopt a crouching position which would effectively reduce the shock intensity.

The latency of each response on the learning trials was measured by means of a Standard Electric Timer. The timer was started automatically when the guillotine door was lifted (to allow the animal to cross the barrier) and

possibility has been obtained in a previous experiment by one of the present authors (2). In that experiment, rats that had been given strong shocks at the end of a short straight alley, and who were therefore presumably quite fearful, exhibited vigorous avoidance responses when placed back into the alley even when no shock was present. In Miller's experiment discussed above, the initial training procedure was also such as to reinforce the tendency of his animals to be active when fearful. Such a tendency might be strengthened (by fear reduction) in the case of those animals that learned to escape, and extinguished in the case of those that failed to learn, thus permitting the crouching response to become dominant in the latter group.

stopped when the door was lowered following a response.

Subjects.—The experimental and control groups each consisted of eight naive albino rats between 60 and 120 days of age. Five of the animals in each group were females, three were males. Within each sex, animals were assigned at random to the two groups.

Training Procedure.—The purpose of the training trials, as in Experiment I, was to develop in the experimental animals a conditioned fear response to the tone-light stimulus. These animals received a total of 22 training trials (as contrasted with 40 in Experiment I); 10 trials were given on each of two successive days and two on the third day. The trials were alternated, half of them being administered in one compartment and half in the other. Each trial consisted of a nine-sec. presentation of the conditioned stimulus, with the interrupted shock presented during the last six sec. of the period. Normally, the shock was set at 150 volts, but occasionally it was raised to 180 if an animal showed no signs of receiving the shock. Successive training trials were run at intervals of three min. One min. after a trial, the animal was moved to the opposite compartment where the next trial followed in two min. After the last trials of the first two days, the animals remained in the box for two min. before being returned to their home cages. Two min. after the second trial of the third day, the animals were removed to a carrying cage, where they remained for five min. before being returned to the apparatus for the learning trials.

All animals were run under a 22-hour hunger drive. They were fed in separate feeding cages one hour after the completion of each day's trials. The purpose of the hunger drive was to raise the general activity level of the animals and hence to increase the probability that the desired response of crossing the barrier would occur promptly on the initial learning trials.

The procedure employed in the training of the control animals was identical with that described above for the experimentals, except that the controls were never shocked.

Testing Procedure.—On each test (learning) trial an animal was placed in one of the compartments, whereupon the door was lifted and the light-tone stimulus was presented *without shock.* As soon as the response of crossing the hurdle occurred, the light and tone were shut off and the door was lowered. After the lapse of two min., the animal was returned to the first compartment for the next trial. In the event that the barrier-crossing response did not occur within one min., the light-tone stimulus was terminated and the door was lowered, the animals being left in the compartment for an additional min. At the end of this period, they were lifted out of, and immediately replaced in, the same compartment and a new trial was begun. The test trials for both groups were identical, all animals receiving 40 trials, 10 on each of four successive days. The test trials for half of the animals in each group consisted in going *from* the compartment in which they had received their last training trial; the other half went *into* the compartment where the last training trial had been given.

Results and Discussion.—The major findings of the second experiment are summarized in Table III, where the mean log latencies (plus 1.0) for successive blocks of five trials are given. These values are plotted in Fig. 2 to the same scale as that of Fig. 1. The results of tests of significance applied to the data are given in Table IV.

From the curves of Fig. 2, it is apparent that, in broad outline at least, the results of the second experiment parallel and confirm those of the first. All of the eight experimental animals learned the new response, and a comparison of the group means for the first and last blocks of five trials shows that the decrease in latency was highly significant. The control animals, by contrast, not only showed no

TABLE III

MEAN LOG LATENCIES (PLUS 1.0) FOR SUCCESSIVE BLOCKS OF FIVE LEARNING TRIALS

	Trials							
	1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40
Control Group	2.09	2.26	2.14	2.35	2.10	2.39	2.19	2.50
Exper. Group	2.02	1.50	1.23	0.94	1.08	1.19	1.10	1.25

TABLE IV

TESTS OF THE SIGNIFICANCE OF DIFFERENCES BETWEEN VARIOUS MEANS OBTAINED FROM THE EXPERIMENTAL AND CONTROL GROUPS

Trials or Groups Compared	t	d.f.	P
1. Trials 1–5 vs. 36–40 (Exper.)	4.48	7	<.01
2. Trials 1–5 vs. 36–40 (Cont.)	6.03	7	<.01
3. Exper. vs. Cont.: Trials1–5	0.45	14	<.70, >.60
4. Exper. vs. Cont.: Trials 36–40	6.61	14	<.01
5. Exper. vs. Cont.: Mean of all trials	9.06	14	<.01

improvement in performance, but instead showed a significant decrement. The general thesis concerning the reinforcing effect of fear-reduction thus receives additional experimental support.[5]

When one compares the curves for the two control groups in the first and second experiments, it is seen that they are roughly alike in absolute height and both show similar cyclic fluctuations in latencies with successive blocks of trials. The two curves differ in that the one for the second control group starts at a lower point and ends at a higher point than that for the first group. The fact that the second group shows a significant increase in latency may be the result of differences between the two conditioned stimuli. The somewhat raucous buzzer in Experiment I could well have been annoying to the animals, and its cessation following a response might have functioned, therefore, as a reinforcing event. Such reinforcement would tend to counteract increases in response latency resulting from the weakening of exploratory tendencies.

A comparison of the two experimental groups reveals that the second showed a marked superiority (shorter latencies) over the first at all stages of learning. Furthermore, the second group differed much more widely from its comparable control group than did the first. Evidently the altered procedures of the second experiment led to more efficient learning. It is impossible, however, to determine from the data just which procedural modifications were primarily responsible for this increase in efficiency.

One feature of interest regarding the curves for the experimental groups is that the animals in the second experiment reached their maximum level of proficiency by the 20th trial and from then on exhibited a fairly progressive decline in performance. This was not the case in the first experiment. Although a statistical comparison of trials 16–20 with trials 36–40 for the second experimental group yielded a non-significant t of 1.7, six of the eight animals had longer

[5] Since the control-group animals were never shocked, there is a possibility that the experimental animals learned to jump the barrier simply to escape from a compartment in which they had been shocked. The response might have been reinforced if, for some obscure reason, the cues of the escaped-into compartment aroused less anxiety than those of the escaped-from compartment. Subsequent to the preparation of this article, an additional control group of eight animals was run to test this possibility. These new animals were trained under precisely the same conditions as were the members of the experimental group in Experiment II. On the subsequent learning trials, however, both the light-tone stimulus and the shock were omitted. The performance of these animals was quite similar to that of the controls in Experiment II, no learning being exhibited. The mean log latencies (plus one) for successive blocks of five trials were 2.26, 2.22, 2.24, 2.56, 2.45, 2.52, 2.44, and 2.60.

mean latencies on the later block of trials than on the earlier one. It is possible, therefore, that the barrier-crossing response was becoming extinguished in spite of the reinforcement provided by fear reduction. Such a decrement in performance could occur as the result of the accumulation of fatigue or work inhibition, even if the level of fear and the reinforcement it provided remained unchanged. But this seems somewhat unlikely, in view of the fact that the response was not especially effortful and the trials were spaced at intervals of a little over two minutes. On the other hand, the decrement in performance could be attributed to a partial extinction of the fear response with a consequent loss in its capacity to provide both an increment to the drive and adequate reinforcement for the jumping response. But if the fear did extinguish, the question immediately arises as to why the reinforcing property attributed to fear-reduction could apparently strengthen the jumping response but not the fear response itself. To our knowledge, there is as yet no completely satisfactory answer to this question; and any attempt to consider the problems which it raises concerning the acquisition and extinction of fear would take us far beyond the intended scope of the present paper.

One of the important outcomes of the second experiment is the manner in which the data bear, though somewhat obliquely, it is admitted, upon the problem of crouching discussed previously. In this regard, it should be noted that the mean scores on the first five-trial block for the experimental and control groups are almost identical, there being no statistical

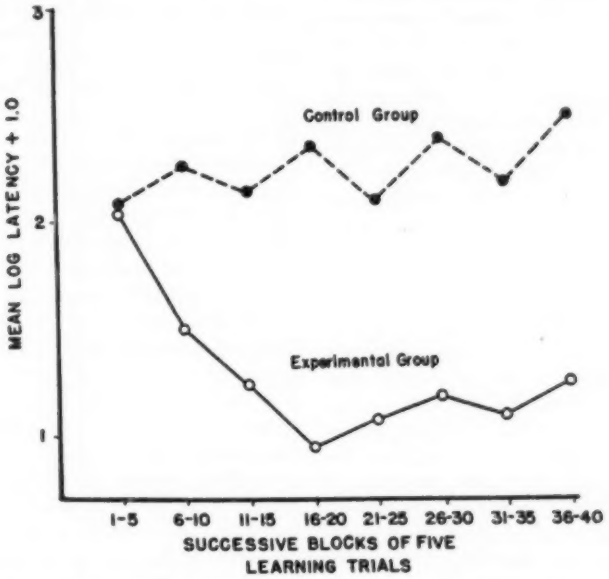


FIG. 2. A graphic presentation of the values listed in Table III. The resulting curves are comparable to those in Fig. 1, and reveal the marked superiority of the fearful experimental animals over the non-fearful controls in the learning of the barrier-crossing response in the second experiment.

basis for the rejection of the null hypothesis. In the first experiment, however, the experimental group was significantly *inferior* to its comparable control group on the first five trials. Now, if the assumption is made that long response latencies on early trials are indicative of crouching (which was not, of course, measured directly) it follows that the animals in the second experiment crouched less (relative to their own controls) than did those in the first experiment. At first thought it might seem that such a reduction in crouching could be attributed to the fact that the animals in the second study were hungry whereas those in the first were not; but this hypothesis may be rejected on the grounds that both the controls and the experimentals in the second study were tested under the same conditions of food deprivation. More reasonably, it could be argued that the degree of immobility in the second experiment diminished either because the fearful animals were less fearful (they received fewer shocks) or because the experimental conditions (pulsating shock, etc.) were less favorable for the learning of the freezing responses. In any event, it seems fairly certain that the experimental animals in the second study *were fearful*, since they readily acquired the new response when it was followed by the cessation of the fear-arousing conditioned stimulus, and *in spite of the presence of this fear they did not crouch more on the early trials than did their non-fearful controls*. Accordingly, we would surmise that fear is not always accompanied by crouching and that the procedural changes of the second experiment probably acted to diminish crouching by reducing the opportunities for its acquisition.

Finally, it should be pointed out that the lack of a significant difference between the performance of the experimental and control groups on the first five-trial block can be interpreted as indicating not only that fear is not always accompanied by crouching, but also that it does not always lead to an increase in general activity level. As in the case of the first experiment, it can be assumed that the *energizing function* of the acquired drive of fear is to intensify whatever responses are dominant, with both innate and acquired habits or predispositions being the determiners of response dominance. As a consequence, almost any degree of overt activity, ranging from vigorous action to rigid immobility, could be exhibited by fearful animals if the appropriate habits were present.

Summary and Conclusions

1. Two experiments have been described in which an investigation was made of the assumption that fear functions as a drive to motivate or energize behavior and that fear-reduction serves as a reinforcing event in the learning of new responses. In both studies, the methods employed in establishing the fear reaction and in measuring its reinforcing properties were designed to minimize the possibility of arousing some other emotional state such as frustration or conflict to which the results might be attributed instead of to fear. The two experiments differed with respect to certain details of procedure, the results of which are believed to be of importance in the interpretation of fear-motivated behavior.

2. The general procedure of both studies involved a number of training trials during which rats were placed in an oblong box and given paired presentations of a conditioned stimulus and an electric shock. Control animals received the conditioned stimulus

but not the shock. On subsequent learning trials the conditioned stimulus was presented alone to all animals and an opportunity was provided for them to perform a new response of crossing from one side of the box to the other by jumping over a central barrier. When the new response was made, the conditioned stimulus was immediately terminated.

3. The assumptions underlying this procedure were: (a) that the paired presentation of the conditioned stimulus and shock, even though no specific escape response was systematically reinforced, would lead to the development of a conditioned fear reaction elicitable by the conditioned stimulus alone; (b) that the conditioned fear would motivate the behavior of crossing the barrier; and (c) that the reduction in fear, occasioned by the cessation of the conditioned stimulus following the new response, would act to strengthen the tendency to perform that response.

4. Since in both experiments the fearful animals learned the new response, whereas their comparable controls did not, the conclusion is drawn that fear-reduction functions much like other drive-reductions to reinforce new responses. The data do not indicate, however, that fear, in spite of its apparent drive properties, is necessarily accompanied by an increase in overt activity. Instead, it appears that fear acts to intensify whatever response is dominant at the moment, whether it be a response of crouching or one of a more active variety. Although the determination of response dominance may be a function in part of innate factors, significant changes in the characteristics of the dominant response to fear can apparently occur as the result of learning.

(Manuscript received January 11, 1949)

References

1. Arnold, Magda B. Physiological differentiation of emotional states. *Psychol. Rev.*, 1945, **52**, 35–48.
2. Brown, J. S. Gradients of approach and avoidance responses and their relation to level of motivation. *J. comp. physiol. Psychol.*, 1948, **41**, 450–465.
3. Farber, I. E. Response fixation under anxiety and non-anxiety conditions. *J. exp. Psychol.*, 1948, **38**, 111–131.
4. Freud, S. *The problem of anxiety.* New York: Norton, 1936.
5. Hull, C. L. *Principles of behavior.* New York: Appleton-Century, 1943.
6. May, M. A. Experimentally acquired drives. *J. exp. Psychol.*, 1948, **38**, 66–77.
7. Miller, N. E. Studies of fear as an acquirable drive: I. Fear as motivation and fear-reduction as reinforcement in the learning of new responses. *J. exp. Psychol.*, 1948, **38**, 89–101.
8. Miller, N. E., & Dollard, J. *Social learning and imitation.* New Haven: Yale Univ. Press, 1941.
9. Mowrer, O. H. A stimulus-response analysis of anxiety and its role as a reinforcing agent. *Psychol. Rev.*, 1939, **46**, 553–565.
10. Mowrer, O. H. An experimental analogue of "regression" with incidental observations on "reaction-formation." *J. abnorm. soc. Psychol.*, 1940, **35**, 56–87.
11. Mowrer, O. H. Anxiety-reduction and learning. *J. exp. Psychol.*, 1940, **27**, 497–516.
12. Mowrer, O. H., & Lamoreaux, R. R. Fear as an intervening variable in avoidance conditioning. *J. comp. physiol. Psychol.*, 1946, **39**, 29–50.
13. Shaffer, L. F. *The psychology of adjustment.* Boston: Houghton Mifflin, 1936.

THE ACQUISITION OF A BLACK–WHITE DISCRIMINATION HABIT UNDER TWO LEVELS OF REINFORCEMENT[1]

BY BRADLEY REYNOLDS

University of Missouri

Introduction

I

In his Postulate 4, Hull (4, p. 178) has proposed a functional definition of *habit strength* ($_sH_R$). One of the parameters entering into the equation is the amount of reinforcement. Specifically,

$$_sH_R = M(1 - e^{-kw}), \qquad (1)$$

where:

M = the limit of growth for habit strength
e = the base of common logarithms
w = the amount of reinforcement
k = an empirical constant

This equation is based upon results from experimentation by Gantt (2) and Grindley (3). The final worth of the equation must be demonstrated by its usefulness. It will not be determined by considerations of origin. However, we should note two facts. First, the data offered as support for the formulation are exactly those upon which the form of the equation depends. Second, these same data are certainly restricted in quantity. It seems legitimate, then, for the learning theorist to raise two questions. How general is the empirical relationship observed by Gantt and Grindley? Can the Gantt and Grindley results be shown to follow from a theoretical formulation differing from that offered by Hull? In what follows some tentative answers to these questions will be examined.

II

Hull has taken from the Gantt study data for one dog. This animal was trained to salivate to four different conditioned stimuli. Associated with each conditioned stimulus was a different amount of food—½, 1, 2, and 12 gm. The mean amount of salivation at the limit of training was found to be a positive function of the amount of reinforcement.

Grindley (3) trained five groups of chicks to make a simple locomotor response. Reinforcement was by way of 1, 2, 4, 6, and 0 grains of boiled rice. Hull has plotted the reciprocal of the mean action time for the last five of seven trials against the number of grains of rice. The resulting curve would seem to indicate that "the rate of learning is an increasing monotonic function of the amount of the agent employed at each reinforcement" (4, p. 127).

The studies of Gantt and Grindley have two common characteristics. First, the character of the unlearned, consummatory response upon which the learned response is based changes with manipulation of the amount of reinforcement. Amount of salivation is a positive function of amount of food presented to the animal. The strength of the chick's response to rice is a positive function of the amount of rice. Second, learning is measured on the same dimension along which the consummatory response shows variation. Amount of salivation is the measure of conditioning employed by Gantt. Strength of response, as evidenced by action time, is used as the measure of learning in the

[1] The study reported in this paper was carried out during the writer's tenure as research professor in the Graduate School of the University of Missouri. The research was supported in part by a grant from the University Research Council of the University of Missouri. The writer is now at the Human Resources Research Center, Lackland Air Force Base, Texas.

Grindley experiment. The hypothesis we shall examine now states that both these characteristics just noted become necessary experimental conditions if Equation 1 is to hold empirically. We shall consider some further explanation of the hypothesis using the Gantt and Grindley experiments for illustration. The discussion will be confined to those aspects of the hypothesis which bear directly upon the problem attacked in the present study. We will refer to the more general theoretical relation stated in Equation 1 as the S (stimulus) hypothesis. The hypothesis to be examined here will be designated the R (response) hypothesis.

In the Gantt study we have the case of an animal rewarded now with ½ gm. of food and now with 12 gm. of food. Paired with each of these reinforcing stimuli is a different conditioned stimulus. We will refer to these latter as S_1 and S_2. After a given number of paired presentations of S_1 with ½ gm. and S_2 with 12 gm. of food, the amount of conditioned salivation to S_2 is greater than conditioned salivation to S_1. The question which arises at this point is: are S_1 and S_2 conditioned to the same response with different degrees of habit strength; or are they conditioned to different responses with the same degree of habit strength? According to the R hypothesis, S_1 and S_2 are conditioned to different responses with the same degree of habit strength. An animal shows a greater amount of salivation to 12 gm. and a lesser amount to ½ gm. These are taken as different responses. The animal comes then to salivate to S_1 that amount which approaches that appropriate for the ingestion of ½ gm. of food, and to S_2 that amount which approaches that appropriate for the ingestion of 12 gm.

Grindley's study involves the use of groups of animals, each group trained with a different level of reward. Presumably the stimulus situation is the same for all groups. The consummatory response to food corresponds to theunconditioned salivary response in Gantt's study. We will consider here that the consummatory response involves the total pattern of activity of the chick in the presence of food. This response can vary in vigor, rapidity of appearance, in the degree to which the animal is involved in the response, in the extent to which the response tends to inhibit other ongoing activities of the animal, and so on. We will use the term *strength* in referring to variations in all these characteristics. For the chick, as for the rat, this consummatory response is to a great extent a running, seizing, eating response. During the eating phase of the response, short, quick movements are characteristically present. The consummatory response varies in strength as the amount of rice presented varies. Six grains of rice evoke a response of greater strength than does one grain of rice. According to the R hypothesis the stimuli incident in the maze situation are conditioned to one consummatory response when six grains of rice are used, and to another consummatory response when one grain is used. The running, organism-involving phase of the consummatory response which tends to move back in time towards the stimuli incident in the fore area of the runway, is assumed to furnish the basis for the development of the locomotor response. This phase of the consummatory response has a greater strength when the total consummatory response is stronger. It is an anticipation of the consummatory response or, as we will call it here, a replication of the consummatory response. In the Grindley study the measure of learning is simply a measure of the strength of the replicate response.

We turn now to a consideration of experimental situations where measurement of learning does not involve direct measurement of a replication of the consummatory response. We should anticipate that in many of these the rate of learning will show some relationship to the amount of reinforcement. In many animal experiments the delay of reinforcement is a function of speed of locomotion. In such experiments rate of

learning should be related to amount of reinforcement. There is very probably a relationship between inhibition determined by the reinforcing state of affairs and the amount of reinforcement. It is difficult to specify this relationship with any exactness at the present time. Where learning depends upon a regular occurrence of the unconditioned response a relationship between learning and amount of reinforcement should exist. This should be the case where frequency of unconditioned response is a function of intensity of unconditioned stimulus. We should expect also that the amount of reinforcement will show some relationship to the rate with which the animal comes to make those responses which the particular learning task requires. For example, if an animal is to learn to turn right in a simple T-maze it is necessary that the animal move from the starting box into the runway, on to the choice area, and turn one way or the other. In the discrimination situation the animal must respond by moving into the choice area and approaching one side or the other of the stimulus pair. The rate with and the extent to which the animal becomes involved in the activity required by the learning situation is determined by the strength of the consummatory response.

Fundamentally the problem of the effect upon learning of variation in the amount of reinforcement depends upon the relationship of the consummatory response to the habit to be learned. We shall expect some positive effect in most situations, since in most situations increase in the strength of the consummatory response and of its replication will tend to facilitate learning. Where learning involves simply acquiring a replicate response of a given strength, variation in the amount of reinforcement will have its greatest effect. Where there is least relationship between the replicate response and the habit to be learned variation in the amount of reinforcement will have least effect. In some instances increased amount of reinforcement may lead to a decreased rate of learning.

Purpose

The experiment to be reported here was designed to answer one question: what is the effect of variation in the amount of reinforcement in a learning situation where the response to be learned differs qualitatively from the consummatory response to the reinforcing stimulus? More specifically, is a larger amount of food reward associated with a more rapid rate of acquisition of a black-white discrimination habit, and a smaller amount with a less rapid rate?

Procedure

Apparatus.—The apparatus employed in the present study was an adaptation of the conventional black-white discrimination box as described by Ehrenfreund (1). Reasons for departing from the more conventional design were two-fold. It was desired that the following time intervals be kept at a minimum: (a) that between the introduction of the animal into the box and the occurrence of the choice response; (b) that between the incidence of the correct response and the appearance of the reinforcing stimulus.

The runway into the choice area was 12 in. in length. The length of the choice area was 8 in. Facing the choice area were two cloth curtains, one black, one white, and measuring 4 in. horizontally and 5 in. vertically. These curtains screened compartments 2½ in. long with a sunken food receptacle 1¼ in. in diameter and ¼ in. in depth. The end of the food compartment was closed with a metal baffle. The bottom of the baffle was immediately behind the food receptacle and the top was at the point where the curtains were attached. The apparatus is pictured in Fig. 1.

Pre-training.—Thirty-seven male albino rats, 125 to 175 days old, were pre-trained. Animals in groups of three to five each were placed in an unpainted training alley. The alley was four feet long, four in. wide and four in. high (inside dimensions). It was covered on top with hardware cloth. The inside area in the alley was divided into three equal sections by two black cloth curtains. The rats were allowed to move about in the alley for 15 min. If all animals in a group tended to move to one end of the alley and remain there, the animals were separated and one or two placed in each section of the alley.

The animals were removed from the training

alley and placed in a metal pail covered on the bottom with wood shavings. Each animal was then handled for three to five min. The animals were returned to the pail and fed one gram of food pellets. Equal number of 30, 60 and 160 mgm. pellets were used.

The whole procedure outlined above was repeated following an interval of 24 hours. All animals had been deprived of food 24 hours at the time of pre-training. The regular daily feeding was 12 gm. of Purina laboratory chow. The food pellets were made from a mixture of four parts laboratory chow to one part white flour.

In the pre-training period animals were given opportunity to extinguish any negative responses towards the curtains and to acquire a positive response to the food pellets.

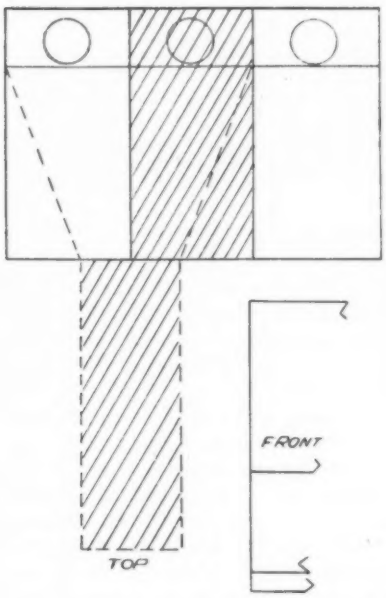


FIG. 1. Floor plan of black-white discrimination apparatus together with a schematic detail of the front projection. The latter projection shows endboard above and opening into food compartment. Cross hatched lines indicate black areas. The dashed lines show the sides of the apparatus bounding the choice area. These sides were painted black. The endboard was painted white above white food compartments, and black above the black food compartment.

Training.—Part of the training procedure partook of the character of pre-training. Because of the nature of the problem attacked it seemed imperative that the amount and number of reinforcements be rigidly controlled throughout the whole period of training and pre-training. It seemed most convenient to begin training in the discrimination apparatus with no other pre-training than that described above. It was anticipated that some animals would be discarded during the early trials, and further, that more of these would be in the low reinforcement group than in the high reinforcement group.

On the first training night, each animal was given five trials in the apparatus with the curtains removed. A food pellet was placed in the white compartment. On the following night five more trials were given with the curtains removed. Any animal who, at the end of the first two nights of training was refusing to leave the starting alley, 'freezing' at the choice area, failing to make a choice response, or refusing to take and eat the food pellet, was eliminated from the experiment.

On the third and succeeding nights, each animal was given 10 trials, run continuously, with the curtains in place. Training was by the correction method and was continued until the animals chose white 18 times in 20 trials, beginning at the 11th trial. At the beginning of training animals were assigned at random to one of two groups. One group (LR) was rewarded with a food pellet weighing 30 mgm., the other group (HR) with a food pellet weighing 160 mgm. Animals were fed 12 gm. daily, including the amount used for reinforcing. The 160-mgm. pellet group was fed immediately following the completion of the nightly training. The 30-mgm. group was fed one hour following the completion of the last trial each night.

RESULTS

Table I contains mean number of trials required by both groups to reach the learning criterion together with estimated sigmas for the popula-

TABLE I

MEAN NUMBER OF TRIALS REQUIRED FOR THE ATTAINMENT OF THE LEARNING CRITERION

Group	Mean	σ
LR (30 mgm.)	43.71	14.66
HR (160 mgm.)	44.0	18.84

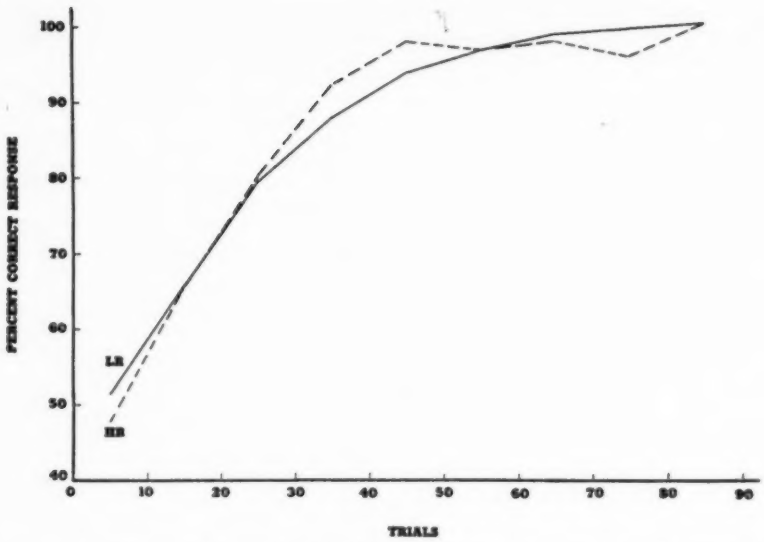


FIG. 2. Percent correct response plotted against trials for two groups of animals, one of which (LR) was trained with 30 mgm. food reinforcement; the other (HR) with 160 mgm. food reinforcement

tions sampled. The LR group mean is 43.71 and the HR group mean is 44.0. The sigmas are 14.66 for the LR group and 18.84 for the HR group.

Acquisition curves for percent correct response are shown in Fig. 2. The curves have been plotted under the assumption that animals attaining the criterion will respond without error if training is continued with these animals.

In Fig. 3, mean response times for the first 35 trials have been plotted against intervals of five trials. The *N*'s for the last two intervals are 69 and 55 for the LR group and 66 and 56 for the HR group.

Table II contains mean response times for the first 35 trials, by 5-trial intervals, broken down into response times for trials where the animal's first choice was to black and for trials where the first choice was to white. The differences between the interval means for each choice within groups are also given. Data for the 6–10th trial interval were analyzed on the basis of the responses for each animal. The means for response times for first choice to black and to white were determined for each animal. The differences between these means were calculated within groups and the median difference for each group was determined. Choice of the median as the statistic to be used was dictated by the fact that certain measures were indeterminate. Measures were considered indeterminate whenever *N* for black or white choices was zero. If all responses were to the white side the measure was taken to be below the median; if all were to black, above the median. The significance of these data will be discussed below.

Nine animals were discarded during the first 10 training trials. Eight of these were from the LR group.

TABLE II

MEAN RESPONSE TIMES FOR FIRST CHOICE OF BLACK (B) AND FIRST CHOICE OF WHITE (W) FOR TRIALS 1–35

Group	HR (160 mgm.)		LR (30 mgm.)		HR (160 mgm.)	LR (30 mgm.)
Trials	B	W	B	W	B-W	B-W
1–5	50.41	18.03	67.68	37.72	32.38	29.92
6–10	17.57	15.91	59.52	16.14	1.66	43.38
11–15	23.42	17.30	33.40	33.13	6.12	.27
16–20	14.96	7.78	33.30	16.36	7.18	16.94
21–25	9.57	6.02	12.36	12.56	3.55	−.20
26–30	6.14	4.83	6.86	6.53	1.31	.33
31–35	5.50	2.40	8.08	4.19	3.10	3.89

DISCUSSION

In terms of mean number of trials to reach the learning criterion no difference between the HR and LR groups was observed. Acquisition curves for the two groups are essentially identical. The response time curve for the LR group is above that for the HR group at every interval point. As trials increase, however, there is a tendency for the curves to converge.

All the results just noted follow directly from the R hypothesis. The effects of differences in the strength of the consummatory responses to a smaller and to a larger pellet are to be observed in differences in response times between the LR and HR groups.

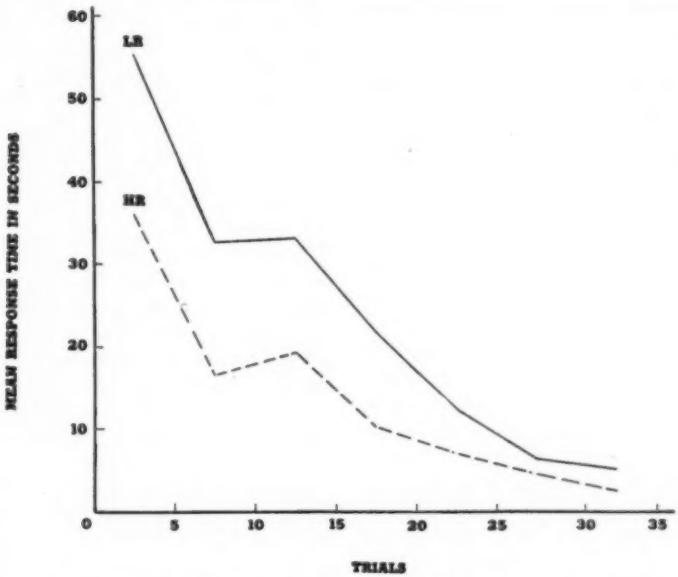


FIG. 3. Mean response time in sec. plotted against trials for two groups of animals, one (LR) reinforced with 30 mgm.; the other (HR) reinforced with 160 mgm. of food

These differences are not paralleled by comparable differences in rate of acquisition of the discrimination habit. Positive confirmation of the hypothesis depends upon just this relationship holding for differences between these two measures of performance. A clear, unequivocal difference exists between the two groups in that measure of performance directly related to the strength of the consummatory response, that is, response time. Such a difference does not exist between the two groups in that measure of performance which is not directly related to the consummatory response, namely, frequency of choice of the positive member of a pair of stimuli. However individual features of the data be evaluated, this more general feature is the one having greatest significance in the experimental test to which the R hypothesis has been subjected. Two particular aspects of the study however, are worth some attention. These will be discussed below.

During the first training trials eight animals were eliminated from the LR group. One animal was eliminated from the HR group. This question presents itself: were slow learners eliminated from the LR group in sufficient numbers to obscure a real difference between the LR and HR groups? The question cannot be answered with any precision. As far as the hypothesis under discussion is concerned a more pertinent question is whether any difference which might have been obscured is sufficiently great that it could not be ascribed to differences in the strength of the consummatory responses involved. It has been assumed that the latter question is to be answered in the negative. The evidence supporting this assumption will be evaluated briefly.

We will assume that individual differences between animals are such that learning scores will distribute symmetrically. The strength of the consummatory response is directly related to the rapidity with which the animal learns the approaching response to the choice situation. Learning the approaching response more rapidly will make for an earlier initiation of the experiences necessary for the animals' learning the discrimination habit. This facilitory effect should make for a piling up of learning scores at the lower end of the distribution. The more rapidly the approaching response is acquired the greater the number of learning scores piling up towards the low end of the distribution. Skew, then, becomes a positive function of the strength of the consummatory response. The mean and the median for the LR group are 43.71 and 41.0, and for the HR group 44.0 and 38.5. Taking as a measure of skewness 3 (Mean-Median)/SD we find the skew for the LR group to be .55 and for the HR group .88. It may be contended that the same results follow if we assume that (1) the distribution of learning scores is always skew, and (2) scores of animals eliminated would have fallen mainly above the third quartile if they had been trained. The main weakness in the latter argument is that it seems unlikely that the correlation between the animals' failure to respond in the situation and trials required to learn the discrimination is as high as the argument requires it to be.

The second point we shall consider has to do with the possibility that the results of the present experiment are to be explained upon the basis of differential reinforcement of the in-

correct response. In developing this argument and evaluating it, we will refer to the response towards black as R− and to the response towards white as R+. When we refer to the interval between R− and R+ we will mean the time between the occurence of R− and the time of occurrence of R+. We turn to an examination of the main features of the argument.

Whenever R− occurs first in a trial it must be followed by R+. Hence R− is always reinforced. The animal acquires two habits, S–R− and S–R+. S–R+ is stronger than S–R− since the delay of reinforcement for S–R− must equal the delay of reinforcement for S–R+ plus the interval between R− and R+. As the interval between R− and R+ decreases the habit strength of R− approaches that of R+. The habit strengths of R− and R+ fluctuate. For the consistent occurrence of R+ it is necessary for the difference between the habit strengths of R− and R+ to be sufficiently great that fluctuations in the habit strengths of R− and R+ will not produce overlapping values. The HR group of animals show shorter response times. Delay of reinforcement is determined in some part by response time. There will be less differences in habit strength between R− and R+ for the HR group than for the LR group. This will make for a reduction of the effect of greater habit strength for R+ for the HR group.

Two points can be made against the argument just presented. Taken without further elaboration it would seem to follow that the LR group will learn more rapidly than the HR group. This objection can be met by any of a number of counter arguments. First, it may be contended that the habit strength for R+ for the LR group must reach a level where it can override competing responses other than R−, e.g., position habits. The habit strength of R+ for the LR group also must be great enough that temporary fluctuations are not extensive enough to bring habit strength for R+ below the level required for response evocation. These factors would make for sufficient retardation in acquisition of the discrimination habit by the LR group to balance out the retardation in acquisition of the discrimination habit by the HR group.

For an understanding of the second point to be made against the interpretation of the results in terms of differential delays of reinforcement we will need to consider the data in Table II. Differences between response times when R− precedes R+ and response times when R+ occurs alone are given in Table II. If we assume that response times for R− and R+ are approximately equal then the tabled differences can be taken as estimates of the delay of reinforcement for R−. The only differences which seem noteworthy are those for the sixth to tenth trial intervals for the HR and LR groups. The difference for the HR group is 1.66 sec. and for the LR group 43.38. These differences have been calculated by combining all response times for all animals for the sixth through tenth trials. It seems worthwhile to analyze further the data by mean response time for each animal for R− and R+. Differences between these means have been obtained for both groups and the medians of the two distributions calculated. This procedure tends to limit undue weighting of the measures of central tendency by extremely large response times. The median for the LR group is 17.12

and for the HR group 8.46. It is not possible to test the difference between these two measures because of the manner in which the medians were obtained. Comparison of the two distributions reveals overall differences in line with the differences between the medians. There is evidence that the delay of reinforcement for R− for the HR group is less than that for R− for the LR group.

More significant than the difference between the estimates of delay of reinforcement for R− for the HR and LR groups are the absolute values for the estimated delays. We would not expect values this large if the interval between R− and R+ is determined solely by the rate of movement of the animals. The length of the delays would indicate that the animals do not respond with R− and then go on immediately to respond with R+. Following R− is a sizable interval during which R+ does not occur. Observation of the behavior of the animals during this interval revealed that the animals (1) showed no specific response, (2) moved about in the fore area of the box, (3) attempted to climb out of the apparatus, (4) returned to the starting chute, with (1) most common. The behavior of the animals is readily explained under the R hypothesis. The animal first develops an approaching response to the choice situation. We will designate this R_a. R_a is a replication of the consummatory response to food. Its rate of acquisition is a positive function of the amount of reinforcement. When the animals respond with R− this is an undifferentiated response to the choice situation. The appearance of R− rather than R+ is probably determined by accompanying response tendencies with respect to position, stimulus intensity, previous responses and so on. When R− is not followed by food R_a undergoes extinction. After a few seconds, or several seconds in some instances, R_a shows spontaneous recovery. Time for recovery is a function of the habit strength of R_a and this in turn is a function of the amount of reinforcement. As a consequence, R_a recovers more rapidly when reinforcement is greater than when it is less. Delay is a function of recovery time. It follows that delay between R− and R+ will be less for the HR group than for the LR group until that point where R_a is sufficiently well established that it shows little if any extinction.

Summary

1. Two groups each consisting of 14 male albino rats were trained on a black-white discrimination problem, using the correction method.

2. One group of animals was rewarded with a food pellet weighing 30 mgm. and the other group with a pellet weighing 160 mgm.

3. The group rewarded with 30 mgm. of food required a mean of 43.71 trials to reach a criterion for learning. The group rewarded with 160 mgm. required a mean of 44.0 trials.

4. Mean response times for the group rewarded with 160 mgm. of food were consistently smaller than mean response times for the group rewarded with 30 mgm. of food.

5. It has been held that the above results are consistent with the hypothesis that the positive relationship between rate of acquisition of a response and amount of reinforcement, as sometimes observed, is limited to responses which can be considered replications of the final consummatory response.

(Manuscript received January 10, 1949)

REFERENCES

1. EHRENFREUND, D. The effect of a secondary reinforcing agent on simple black-white discrimination learning. *Amer. Psychologist*, 1947, **2**, 426.
2. GANTT, W. H. The nervous secretion of saliva: The relation of the conditioned reflex to the intensity of the unconditioned stimulus. *Proc. Amer. physiol. Soc., Amer. J. Physiol.*, 1938, **123**, 74.
3. GRINDLEY, G. C. Experiments on the influence of the amount of reward on learning in young chickens. *Brit. J. Psychol.*, 1929–30, **20**, 173–180.
4. HULL, C. L. *Principles of behavior*. New York: D. Appleton-Century, 1943.

ACQUIRED DISTINCTIVENESS OF CUES: I. TRANSFER BETWEEN DISCRIMINATIONS ON THE BASIS OF FAMILIARITY WITH THE STIMULUS

BY DOUGLAS H. LAWRENCE[1]

Stanford University

INTRODUCTION

In a discrimination problem, any one of a number of different stimulus aspects usually can be designated as the relevant one, i.e., the one that the *S* must respond to in order to be correct. These various stimulus aspects have an initial order of distinctiveness in the sense that some of them are more readily associated with the instrumental behavior demanded in that discrimination than are the other stimulus aspects. This initial order of distinctiveness is determined, presumably, by the principles of perception, such as those emphasized by Gestalt psychology (**3, 4, 5, 6, 12**), and the innate makeup of the organism.

The present experiment is based on the hypothesis that while an *S* is learning new instrumental responses in such a discrimination, this initial order of distinctiveness simultaneously is being modified. If the *S* is trained to respond to some aspect of the situation other than the initially dominant one, then this new aspect will tend to become more distinctive and the other aspects relatively less distinctive. Consequently, when this same cue appears in another discrimination problem, it will be more readily associated with the instrumental behavior demanded by the new problem than it would be without the previous training. Thus, the previous experience of the *S* with various cues, irrespective of the instrumental behavior associated with them, becomes an important determinant of the rapidity of learning in a new situation involving the same cues.

This formulation implies a distinction between (a) the learning involved in the acquisition of the correct instrumental responses in a discrimination situation and (b) the learning involved in modifying the initial order of distinctiveness among the cues. It is assumed that both of these events take place simultaneously during the initial training, but that they can have relatively independent influences on subsequent learning that occurs in the same or a similar situation. It is apparent, therefore, that the test of this hypothesis must be in terms of a transfer experiment so designed as to separate out the influences of these two factors. It must be possible to determine the influence that previous experience with a set of cues in one situation has on learning in a second situation, involving the same cues, when the transfer of overt instrumental responses from the first to the second task is ruled out. The instrumental behavior learned in the first situation must neither facilitate nor hinder the learning of the instrumental responses in the second situation. If transfer effects in the expected direction are still obtained, it supports the idea that this is due to a change in the relative distinctiveness of the cues.

[1] The present experiment is a portion of a thesis presented to the Faculty of the Graduate School of Yale University in partial fulfillment of the requirements for the degree of Doctor of Philosophy. The writer is deeply indebted to Dr. N. E. Miller for generous advice and criticism.

The test employed in this experiment is the amount of transfer that obtains between a simultaneous discrimination and a successive one, and conversely. The justification for the assumption that the responses learned in the simultaneous discrimination neither help nor hinder the learning of the instrumental responses in the successive discrimination is clearer in terms of the diagram in Table I.

In the simultaneous discrimination, the *S* is equally often rewarded for turning right as for turning left in the presence of the same two cues. Consequently, when placed in the successive discrimination, he has equally strong tendencies to turn right or left irrespective of whether or not the white or the black is present on that trial. It is apparent, therefore, that if transfer occurs between the simultaneous and successive discriminations, it cannot be due to the carry-over of the same instrumental response.

With this as the basic transfer situation, the present experiment was designed to test the hypothesis in the following way. Three stimulus dimensions, A (brightness), B (width of goal compartment), and C (texture or roughness of floor), were chosen. On each of these stimulus dimensions, a different group of animals was given preliminary training in a simultaneous discrimination apparatus. All animals were then trained on a successive discrimination in which stimulus dimension A was the relevant cue, i.e., it was the one to which the animal had to respond in order to learn the discrimination, and stimulus dimension B was present as an irrelevant cue, i.e., it was varied in a random manner from trial to trial in a way that was uncorrelated with the rewards and punishments.

The present hypothesis would predict that animals that had learned to respond to dimension A in the simultaneous discrimination would learn the successive discrimination, in which dimension A was the relevant cue, with relative ease. This dimension would have acquired distinctiveness for them as the result of their preliminary training. Animals trained on dimension B, on the other hand, should be retarded in their learning of the successive discrimination. Their previous training would have tended to emphasize the stimulus dimension that was irrelevant in the test situation. Finally, animals trained on dimension C would act as a control group in that they were unfamiliar with both dimensions in the successive discrimination.

Subjects and Apparatus

Sixty male, albino rats approximately 60 days old at the beginning of the experiment were used. Six of these animals were discarded during adaptation training either because of unusual timidity or because of excessive weight loss resulting from the restricted diet.

TABLE I

Cues and Responses in Simultaneous and Successive Discrimination

	Simultaneous Discrimination Cues	Simultaneous Discrimination Response	Successive Discrimination Cues	Successive Discrimination Response
1st Trial	Black on the left White on the right	Approach Black (Turn left)	All Black (Both right and left)	Turn Right
2nd Trial	White on the left Black on the right	Approach Black (Turn right)	All White (Both right and left)	Turn Left

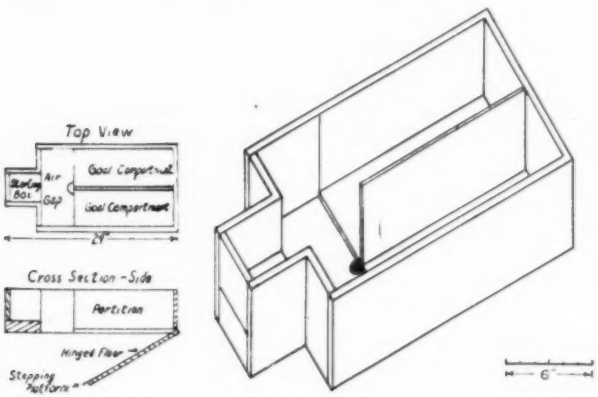
The design of the experiment necessitated the use of three different sets of stimuli. These stimuli were chosen so that they would minimize the need for orientation and at the same time ensure that the animal would be physically stimulated by them at any place in the goal compartment. The three cues, each in three degrees, used in this experiment were as follows: (a) brightness differences obtained by painting the insides of the apparatus either white, neutral gray, or black; (b) width differences obtained by means of movable walls in the goal compartments that resulted in widths of 3, 4, and 5½ in.; and (c) differences in the texture of the floors obtained by covering them with steel screens of 20, 8, and 2 strands to the inch. All possible combinations of these cues were provided for.

The simultaneous discrimination apparatus is shown in Fig. 1. The three walls and the floor of each goal compartment were lined with cardboard of the desired brightness. These carboard linings could be readily interchanged between compartments. New cards were substituted at frequent intervals. The rest of the apparatus including the starting box was painted a neutral gray. False walls could be attached to the outside walls of each goal compartment so as to make the latter any width desired. Likewise, wire screens with various sized mesh could be fastened to the floors. These were always of the same color as the rest of the compartment. The floor of this apparatus was hinged and could be released by the *E* whenever the animal made an error. When this occurred, the animal fell onto a platform 2½ ft. below.

In order to ensure 'deliberate' rather than 'blind' choices, a 4½ in. air gap separated the starting box from the entrance to the goal compartments. An animal had to step across the gap onto the semi-circular platform directly in front of the dividing wall between the compartments. Thus, all choices were made from the same position and with both compartments visible at the same time. In order to enhance the visibility of the cues, the floor of the starting box was an inch higher than the floor of the goal compartments; the animal tended to look down upon the cues. The food cups were attached to the rear walls of the goal compartments. The lid of the apparatus was a solid sheet of heavy glass.

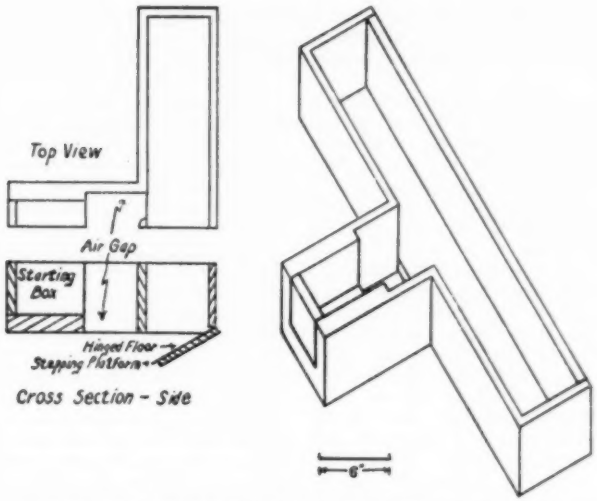
The back wall of the starting box was movable so that the animal could be forced to make a choice within a prescribed time. If an animal made no attempt to step across the gap within 60 sec. after being placed in the apparatus, the rear wall of the starting box was slowly advanced until the animal was forced to make a choice. Once an animal had placed his front feet on the landing platform, however, he was never pushed even though his rear feet remained in the starting box. This position was uncomfortable enough so that all animals would eventually choose rather than remain straddling the gap.

The successive discrimination apparatus consisted of three identically constructed T-



SIMULTANEOUS DISCRIMINATION APPARATUS

FIG. 1. The goal compartments of this simultaneous discrimination apparatus were lined with cardboard of various brightnesses, the floors covered with various sized wire mesh, and the width varied by inserting false side walls. The animals were forced out of the starting box by advancing the rear wall. The cover was a solid sheet of heavy glass.



SUCCESSIVE DISCRIMINATION APPARATUS - T MAZE

FIG. 2. The cues used in this successive discrimination apparatus were the same as in the simultaneous discrimination. Three different T-mazes of this sort were used; one black, one white, and one neutral gray.

mazes. A drawing of one of these is shown in Fig. 2. The starting box section was made as similar as possible to that of the simultaneous discrimination apparatus. The crossarm sections of these mazes were painted, respectively, white, black, and neutral gray. The stem section in each case was a neutral gray. The continuous wall of the crossarm was movable so that the width could be varied. Various sized wire mesh could be attached to the floor. The floor was hinged and could be released by the *E* whenever an error was made. The starting box had a movable rear wall that could be advanced so as to force the animal to step across the gap at the end of 60 sec. The lids of the T-maze were of heavy glass. The food cups were on the end walls of the crossarm.

Both the simultaneous and successive discriminations were run inside an arch-shaped compartment so as to provide even, indirect illumination for the apparatus. This was constructed of large sheets of white cardboard attached to a wooden frame. The base of the arch was 4 ft. wide, its peak was 3 ft. high, and it had a depth of 3½ ft. Its floor was on a level with the floor of the apparatus. Two 40-watt, white fluorescent lamps were placed at the base of each one of the side walls. Two 30-watt lamps were placed at the base of the back wall. The front wall was partly open so that the *E* could have ready access to the apparatus. In this way the illumination of the apparatus was entirely by indirect lighting and no shadows or other inadvertent cues were present.

ADAPTATION TRAINING

Prior to the experiment all animals were tamed by being made thirsty and then being allowed to drink while held by the *E*. Following this they were put on a 24-hour feeding schedule. For two hours a day they had all the dry Purina Laboratory Chow they would eat without water. The food was then taken away and the water bottles returned to the cages. This feeding schedule was continued throughout the experiment. The animals were then given 20 forced trials on the simultaneous discrimination apparatus in order to train them to step across the air gap. All three stimulus dimensions were at their mid-values, i.e., the goal compartments were neutral gray, 4 in. wide and the floors were covered with the eight-strand wire mesh. The same was true of the starting box at this time and throughout the remainer of the experiment. At the beginning of these forced runs, the starting box was moved forward until it touched the stepping platform. Gradually, the gap between them was widened so that by the tenth trial the animals were stepping across the full distance.

Half the forced trials were to the left and half to the right. One each trial the animal was allowed to eat a small pellet of moist food in the food cup.

The following day the animals were given a 'dry run' of 10 trials with the neutral cues still present in order to adapt them to the punishment and to being forced out of the starting box. This dry run consisted of 10 free choices on which the experimenter arbitrarily decided that either the right or left compartment would be 'correct' on that trial. If an animal made an incorrect choice, he was dropped onto the platform, immediately picked up, returned to the starting box, and the trial continued until he chose correctly. If he refused to leave the starting box for more than 60 sec. on any choice, he was forced by advancing the rear wall of the starting box. By means of this dry run most animals tended to get over their initial startle reactions to being dropped or pushed; it also tended to break down position habits. The third day the animals were given a dry run of 10 trials on the T-mazes, again in the presence of the neutral cues.

Experimental Design

A. Preliminary Training: Simultaneous Discrimination

At the end of this adaptation training, the 54 animals were divided randomly into three groups of 18 animals. This first group was trained on the simultaneous discrimination apparatus with black and white as the cues. The other two cues, the width of the compartment and the texture of the floor, were held constant at their mid-values. Half the animals were trained to black as the positive cue and half to white as the positive cue. The second group of 18 animals received exactly the same type of training except that the cues were the two-strand wire mesh versus the twenty-strand wire mesh on the floors of the goal compartments; width and brightness were at their mid-values. The third group was trained to discriminate between a wide (5½ in.) compartment and a narrow (3 in.) compartment. The same order of choices was used for all three groups. Forty trials, 10 trials a day, were given to all animals. By this time all groups averaged better than 90 percent correct choices. Training was given by the correction method outlined in the previous section.

B. First Test: T-Maze Discrimination

As pointed out previously, the test for transfer in this experiment was to have a successive discrimination in which two stimulus dimensions were present on each trial, one as a relevant cue and the other as an irrelevant one. By a relevant cue is meant one that is correlated with the reward so that the animal must respond on the basis of this cue in order to learn the discrimination; by an irrelevant one is meant a cue that is not correlated with the reward and that the animal must 'ignore' in order to learn the discrimination. With the three different stimulus dimensions used in this experiment, there are six different stimulus pairs that can be used on the T-mazes. One such pair is black-white as the relevant cue and rough-smooth as the irrelevant cue. To this pair of stimuli there were assigned three different groups with three animals in a group. The first group had had the black-white cues on the simultaneous discrimination, the second the rough-smooth cues, and the third the wide-narrow cues. Consequently, the first group was familiar with the relevant cue on the T-mazes, the second with the irrelevant, and the third with neither; they should show positive, negative, and no transfer effects respectively. The other five stimulus pairs were treated in the same way. The details are shown in Table II.

The order of trials was arranged so that each of the four possible combinations of the relevant and irrelevent cues occurred equally often in a set of 12 trials, but at the same time the correct response was never more than twice on the same side in succession. If the relevant stimulus was black-white, half the animals were trained to turn right to black and left to white; the other half of the animals were trained in the converse responses. In so far as was possible with three animals in a subgroup, such factors as whether or not an animal had been trained to the black or the white as the positive cue in the simultaneous discrimination were balanced. All animals were given 90 trials, 10 trials a day. The training procedure on the T-mazes was the same as that used on the simultaneous discrimination.

C. Second Test: Simultaneous Discrimination

1. *For the groups that previously were the positive and negative groups on the T-mazes.*— The first test was designed to show transfer from a simultaneous discrimination to a successive discrimination. The second test is designed to show that transfer can occur in the reverse direction, from a successive to a simultaneous discrimination. In order for this second test to be crucial for the hypothesis, it is necessary to control all factors but familiarity with the test stimuli. This was possible in the present design as can be seen by comparing Groups 1A and 2B

TABLE II

TRAINING SCHEDULE

Group	Simultaneous Discrimination	T-Maze Discrimination		Transfer Predicted	Simultaneous Discrimination		Transfer Predicted
		Relevant	Irrelevant		Relevant	Irrelevant	
1A	B-W	B-W	R-S	+	R-S	Wd-N	−
1B	R-S	B-W	R-S	−	B-W	Wd-N	+
1C	Wd-N	B-W	R-S	o	B-W R-S	R-S B-W	+ −
2A	R-S	R-S	B-W	+	B-W	Wd-N	−
2B	B-W	R-S	B-W	−	R-S	Wd-N	+
2C	Wd-N	R-S	B-W	o	R-S B-W	B-W R-S	+ −
3A	B-W	B-W	Wd-N	+	Wd-N	R-S	−
3B	Wd-N	B-W	Wd-N	−	B-W	R-S	+
3C	R-S	B-W	Wd-N	o	B-W Wd-N	Wd-N B-W	+ −
4A	Wd-N	Wd-N	B-W	+	B-W	R-S	−
4B	B-W	Wd-N	B-W	−	Wd-N	R-S	+
4C	R-S	Wd-N	B-W	o	Wd-N B-W	B-W Wd-N	+ −
5A	R-S	R-S	Wd-N	+	Wd-N	B-W	−
5B	Wd-N	R-S	Wd-N	−	R-S	B-W	+
5C	B-W	R-S	Wd-N	o	R-S Wd-N	Wd-N R-S	+ −
6A	Wd-N	Wd-N	R-S	+	R-S	B-W	−
6B	R-S	Wd-N	R-S	−	Wd-N	B-W	+
6C	B-W	Wd-N	R-S	o	Wd-N R-S	R-S Wd-N	+ −

In this training schedule, B-W stands for black-white cues, R-S for rough-smooth, and Wd-N for wide-narrow. Relevant cues are ones that are correlated with the rewards and punishments; irrelevant cues are ones that have no correlation with the reward. Positive transfer (+) is predicted if the group has had previous experience with the relevant cue, negative transfer (−) if the group has had previous experience with the irrelevant cue, and zero transfer (o) if the group has not had previous experience with either of them.

in Table II. The only way in which the two groups differ is that Group 2B learned to respond to rough-smooth in the T-mazes because it was the relevant cue, and Group 1A learned to ignore rough-smooth because it was the irrelevant cue. Thus, if both groups are retrained on a simultaneous discrimination in which rough-smooth is the relevant cue and wide-narrow the irrelevant one, the only reason that their learning rates can differ is that they have had a different type of experience with rough-smooth on the T-mazes. According to the hypothesis, Group 2B, which learned to respond to rough-smooth, should show positive transfer on the simultaneous discrimination, and Group 1A, which had learned to ignore rough-smooth, should show negative transfer. There are five other possible contrasts of this sort: 1B vs. 2A, 3A vs. 4B, 3B vs. 4A, 5A vs. 6B, and 5B vs. 6A.

2. *For the groups that previously were the control groups on the T-mazes.*—The control groups on the T-mazes, the 'C' groups of Table II, provide a slightly different test of transfer when they are retrained on the simultaneous discrimination. In contrast to the groups discussed in the previous paragraph, the control groups were unfamiliar with either the relevant or the irrelevant cues of the T-maze when they began their successive training. Consequently, they could be retrained on a simultaneous discrimination in which both of these cues were again present. For instance, one of the three animals in Group 1C was retrained on a simultaneous discrimination with the same cues having

exactly the same roles, i.e., black-white as relevant and rough-smooth as irrelevant. It should show positive transfer. The other two animals were retrained on the simultaneous discrimination with the same cues but with their roles reversed, i.e., rough-smooth was the relevant stimulus and black-white the irrelevant one. These animals should show negative transfer. The other five 'C' groups in Table II were treated in a similar manner. The 18 animals involved were divided so that half would show positive transfer and half negative transfer.

Training on this second simultaneous discrimination was the same as in the two prior discriminations. All animals were given 40 trials, 10 trials a day.

Results

A. Original Training: Simultaneous Discrimination

The learning curves for the three groups on the original simultaneous discrimination are shown in Fig. 3. It is apparent that the black-white and the rough-smooth discriminations are learned at about the same rate. The wide-narrow discrimination, however, proves to be much more difficult than the other two. This seemed to result primarily from two factors: (a) some animals showed an unusually strong tendency to avoid the narrower compartment and (b) many animals seemed unable to discriminate between the widths of the compartments with any consistency until they had learned to poke their heads into each compartment before making a choice. At the end of 40 trials, however, all three groups of animals were performing with better than ninety per cent accuracy.

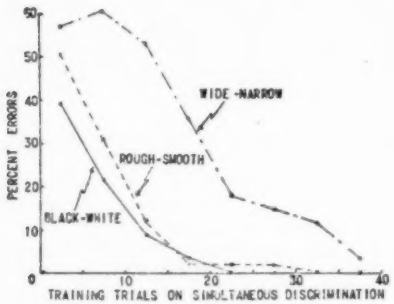


Fig. 3. These learning curves on the simultaneous discrimination are based on 18 animals apiece. The three sets of cues involved were brightness differences (black-white), various sized wire mesh on the floors (rough-smooth), and the relative width of the goal compartments (wide-narrow). All animals were given 40 trials.

B. First Test of Transfer: T-Mazes

According to the hypothesis underlying this experiment, those animals that experienced the same cues on the simultaneous discrimination that later proved to be the relevant cues on the T-mazes should show positive transfer; those who experienced the cues that later proved to be irrelevant should show negative transfer; and those who experienced neither the relevant nor irrelevant cues should not show any transfer effect. The extent to which these predictions are fulfilled is shown in Table III which gives the mean number of trials on which one or more errors were made by the various groups on the 90 T-maze trials. Of the six possible comparisons between positive and negative transfer groups, all are in the predicted direction. Similarly, all of the six possible comparisons between the positive transfer groups and the control groups are in the predicted direction. But of the six comparisons between the negative transfer groups and the control groups, only three are in the predicted direction. On the basis of these rough comparisons, there is considerable evidence of transfer but no reliable indication of the direction of these transfer effects. This is shown graphically in Fig. 4 which gives the learning curves of the combined groups.

TABLE III

ERROR SCORES ON THE SUCCESSIVE DISCRIMINATION

(*N* is three in each case)

Group	Mean	Predicted Transfer	Group	Mean	Predicted Transfer	Group	Mean	Predicted Transfer
1A	9.67	+	3A	13.33	+	5A	27.33	+
1B	22.00	−	3B	24.33	−	5B	41.00	−
1C	26.67	0	3C	14.33	0	5C	39.00	0
2A	25.33	+	4A	19.67	+	6A	24.33	+
2B	30.00	−	4B	29.33	−	6B	25.00	−
2C	37.00	0	4C	22.00	0	6C	28.33	0

This table shows the mean number of trials on the T-mazes on which one or more errors were made. If an animal made more than one incorrect choice on a given trial, it was still recorded as only one error. The training schedule for each group and the basis for the predicted transfer are shown in Table II.

A more sensitive test is provided by analysis of variance techniques. The 18 subgroup variances are relatively homogeneous as indicated by Bartlett's test (10). The corrected chi-square value is 21.88 with 17 d.f., indicating that 20 times in a 100 greater heterogeneity between variances would result from random sampling alone. There is also very little evidence of correlation between the means and variances of the subgroups.

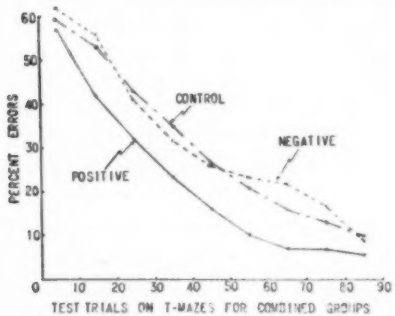


FIG. 4. Each of these learning curves on the successive discrimination is based on the average of 18 animals. On each trial there were two cues present, a relevant one correlated with the rewards and punishments and an irrelevant one that was uncorrelated with them. The positive transfer group had previously experienced the relevant cue in the simultaneous discrimination, the negative group the irrelevant cue, and the control group neither of them.

Consequently, no transformations were made in the raw data; each animal was assigned a score that was the number of trials on which he made one or more errors during the 90 trials on the T-mazes.[2] These are the scores that enter into the following analysis.

TABLE IV

ANALYSIS OF VARIANCE COMPARING THE POSITIVE, NEGATIVE AND CONTROL GROUPS ON THE T-MAZES

Comparison	d.f.	Variance
1. Negative vs. Control	1	7.11
2. Positive vs. Other Two	1	811.26
3. Between Stimuli	5	420.46
4. Interaction	10	56.32
5. Error	36	51.20

$F_{(1 \text{ vs. } 5)} = 0.14$; $F_{(2 \text{ vs. } 4)} = 15.84^{*}$; $F_{(3 \text{ vs. } 5)} = 8.21^{*}$

* Significant beyond the one percent level of confidence

[2] The number of initial errors was chosen as the most representative score because many of the animals seemed to learn early in training that being punished for a wrong initial choice was an excellent reason for choosing the opposite side when replaced in the starting box. Consequently, their total errors showed a rapid drop at first without any noticeable improvement in initial errors. However, all the analyses reported in this section were also computed using total errors instead of initial errors; the conclusions were the same in each case.

The results are shown in Table IV. It is apparent in this table that the difference between the negative transfer group and the control group is even smaller than would be expected 50 times in 100 on the basis of random sampling alone. Because of this lack of difference between the negative transfer and the control group, they were pooled to form one overall control group. The comparison between this combined group and the positive transfer group gives an *F*-value that is well beyond the one percent level of confidence. Consequently, while there is no basis for determining the direction of transfer effects in these data, the evidence for the existence of transfer is convincing.

The only other significant *F*-value in these data is contributed by the five degrees of freedom associated with the differences in difficulty of the six cue combinations used on the T-mazes. This is a consequence of the fact that the T-mazes are relatively easy when black-white is the relevant stimulus dimension, somewhat more difficult when wide-narrow is the relevant stimulus, and the hardest of all when rough-smooth is the relevant stimulus. This indicates that the amount of transfer is not necessarily determined by the difficulty of the discrimination. It is true that the black-white discrimination is the easiest and shows the most evidence of transfer, but the rough-smooth discrimination shows more transfer than does the wide-narrow, even though the latter is a somewhat easier discrimination.

C. Second Test of Transfer: Simultaneous Discrimination

1. *For the groups that previously were the positive and negative groups on the T-mazes.*—After completing their T-maze training, the six positive and the six negative transfer groups on that test were paired and retrained on a simultaneous discrimination. The basis of this pairing was discussed in the previous section on Experimental Design. This resulted in six new positive and in six new negative transfer groups. The learning curves for these new transfer groups on the simultaneous discrimination are shown in Fig. 5. Again the positive transfer animals learn more rapidly than do the negative transfer animals.

The data from these groups were analyzed in the same way as in the previous test and the results are shown in Table V. The difference between the positive and negative transfer groups when tested against the error term is significant at well beyond the one percent level of con-

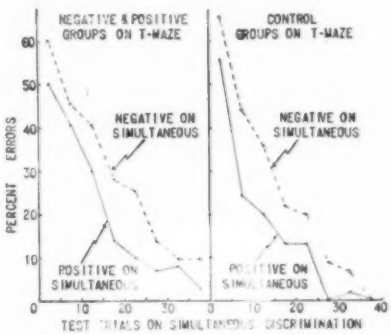


FIG. 5. The curves on the left represent the performance of the positive and negative groups of the successive discrimination when they were retrained on the simultaneous discrimination. The relevant cue in this simultaneous discrimination was one that all animals had experienced on the T-mazes. The positive transfer group in this test had experienced it as the relevant cue on the T-mazes, whereas the negative transfer group had experienced it as the irrelevant cue on the T-mazes. The curves on the right represent the performance of the control groups of the successive discrimination when they were retrained on a simultaneous discrimination of much the same nature.

TABLE V

ANALYSIS OF VARIANCE COMPARING THE POSITIVE AND NEGATIVE GROUPS ON THE SIMULTANEOUS DISCRIMINATION

Comparison	d.f.	Variance
1. Positive vs. Negative	1	110.25
2. Between Stimuli	5	29.65
3. Interaction	5	37.12
4. Error	24	11.28

$F_{(1 \text{ vs. } 4)} = 9.78^{*}$; $F_{(2 \text{ vs. } 4)} = 3.29^{**}$; $F_{(2 \text{ vs. } 3)} = 2.97$

* Significant beyond the one percent level of confidence

** Significant between the one and five percent levels of confidence

fidence. This indicates that within the limits of this experiment transfer also takes place from the T-mazes to the simultaneous discrimination as well as in the reverse direction. The interaction variance between transfer effects and stimulus combinations, however, is significant between the one and five percent levels of confidence. When the difference between the positive and negative transfer groups is tested against the interaction variance, the *F*-value is short of significance at the five percent level of confidence. The conclusion must be, therefore, that while there is definite evidence of transfer in this second test of the experiment the generality of the results may be limited by the type of stimuli that are employed in the test situation.

2. *For the groups that previously were the control groups on the T-mazes.* —The six control groups on the T-mazes were treated separately on this second test for reasons stated in the section on Experimental Design. Because of the unequal number of animals in the subgroups, an analysis of variance was not attempted. Instead, the nine animals in the positive transfer group were combined and the nine animals in the negative transfer group were combined. The positive transfer group averaged 6.4 trials on which one or more errors were made whereas the negative transfer group averaged 10.2 trials. The *t*-test based on this difference gives a value of 2.36 with 16 d.f. which is significant between the two and five percent levels of confidence. This confirms the results found for the other groups on this second test of transfer.

DISCUSSION

This experiment indicates that transfer results when an animal learns to discriminate between a pair of cues in a simultaneous discrimination and then learns a new set of responses to the same cues in a successive discrimination. The consistency of this transfer is shown on the first test with the T-mazes; all six of the possible comparisons between the positive and negative transfer groups are in the expected direction. Its generality is suggested by the fact that it occurs on the shift from the T-mazes to the simultaneous discrimination as well as in the converse direction. It is demonstrated also by the fact that transfer is evident on the three different sets of stimuli employed.[3]

The question of whether or not both positive and negative transfer effects occur, however, is not decided by this experiment. The failure to obtain a differentiation between the control groups and the negative transfer groups would tend to indicate that the expected retardation of learning due to previous training on the irrelevant stimulus of the test situation was not obtained. This lack of differentiation, however, may be due to a

[3] The results of this experiment as they apply to the positive and negative transfer groups were verified in an independent, preliminary experiment. Only the black-white and rough-smooth cues were employed.

negative transfer effect in the performance of the control groups as the result of external inhibition. The fact that the control animals were totally unfamiliar with either of the stimulus dimensions in the T-mazes may have resulted in more of a disruption of their performance than in that of the other two groups, each of whom was familiar with one of the two dimensions. In retrospect, it is apparent that the design of the present experiment would have been improved by adapting the control group to the cues in the T-maze prior to the training series. This was not done, so it is impossible to say whether or not the transfer observed is due to a positive effect alone, a negative effect alone, or both conjointly, for depending upon the extent to which the control group was retarded in its learning by external inhibition, any one of these is possible. In the absence of any conclusive evidence as to the direction of these transfer effects, the remainder of the discussion will implicitly assume that both positive and negative effects are present, but that the latter have been obscured due to the external inhibition of the control group.

The design of this experiment does rule out several possible explanations of the transfer that has been demonstrated. (a) As pointed out in the Introduction, the explanation cannot be in terms of the carry-over of the same instrumental response from the learning situation to the test situation. (b) Any explanation based on the idea that the animals have learned some 'general' habit or ability to solve discrimination problems is inadequate because the control and negative transfer groups were given exactly the same training on the simultaneous discrimination as the positive transfer group. (c) Except in the case of the control group, external inhibition resulting from the introduction of unfamiliar cues into the situation cannot account for the differential effect, because both the positive and negative transfer groups were familiar with one cue in the T-mazes and unfamiliar with the other. (d) Similarly, explanations in terms of acquired reward (1) or acquired drive value (7, 8) of the cues in the test situation are inadequate because these factors were balanced for both the positive and negative transfer groups.

Any hypothesis that is to explain this transfer must be based on the idea that the original training in the simultaneous discrimination modified the readiness with which an animal could learn new responses to the same stimuli. The result is much the same as though new cues had been substituted in the stimulus situation that were inherently of a different order of difficulty as measured by the ease with which they were associated with the instrumental behavior. It is in this sense that the original training can be said to have increased the relative distinctiveness of the relevant cues in that situation.

Behavioral theories of learning attempt to account for this apparent change in the distinctiveness of the stimulus situation in two ways. The explanation most frequently used is in terms of orientation behavior, either innate or learned (11). This includes such behavior as learning to look in a given direction or at a specific aspect of the stimulus situation. Orientation behavior acts as a selector mechanism in that it puts the animal into functional relationship with one part of the physical situation and excludes the remainder. Closely allied to this is behavior that modifies the pattern of stimulation at the receptor organ such as focusing the eyes, adjusting the tympanic membrane, and the like. In all these instances there has been a selec-

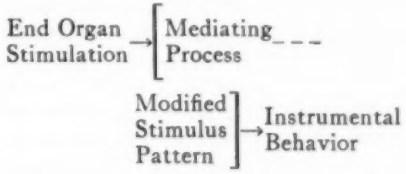
tion or a modification of the physical stimuli in the situation.

The other major explanation used by behavioral theories is in terms of mediating responses or pure stimulus acts (2, 9). These are conceived of as internal processes that are associated through learning with a given pattern of end organ stimulation. These in turn produce a new pattern of stimulation that becomes associated with the overt behavior. It is apparent that this formulation places emphasis on the modifications and transformations made in the stimulus reception processes as a result of previous learning. The readiness with which overt behavior is associated with a given physical stimulus situation depends to a large extent on the characteristics of the mediating response. Some mediating responses facilitate learning because their response-produced-stimuli are more intense or qualitatively more distinctive than are the physical stimuli that give rise to them.

Although mediating responses and orientation behavior are logically distinct, they are usually inseparable in practice. Mediating responses are primarily constructs or conceptual devices and, therefore, unobservable; orientation behavior on the other hand emphasizes overt behavior. The two shade into each other so gradually, however, that it is always possible that orientation behavior is present even though the experimenter is unaware of it. As regards their explanatory function in behavior theory, this difference is unimportant in that both are assumed to have the same role in learning, i.e., the modification of the effective stimulus pattern in any situation.[4]

[4] In the present experiment every effort was made to minimize the need for overt orientation responses. The goal compartments were contiguous, the animal was forced to choose from a point immediately in front of the dividing wall, competing cues in the environment were reduced to a minimum, the relevant cues were chosen so that the animal was certain to be physically stimulated by them while making a choice, and the floor of the starting box was higher than that of the goal compartment so that the animal would tend to look down upon the cues. Consequently, while orientation behavior cannot be eliminated as a possible explanation of the results, it seems highly improbable that it accounts for the transfer observed.

The hypothesis on which this experiment is based is an extension of the mediating response type of explanation. It assumes that mediating processes are always established to some extent during discrimination learning and possibly in all learning situations. The association between the physical stimulus situation and the instrumental behavior is viewed as a two-stage process; the end organ stimulation arouses a mediating process which in turn gives rise to a stimulus pattern that is associated with the instrumental behavior. These relationships are schematized in the following diagram:



In terms of this diagram, the hypothesis states that during learning the mediating process and its accompanying stimulus pattern are gradually established. By the end of learning, the 'modified stimulus pattern' is qualitatively different from what it was at the start of learning; it has acquired distinctiveness in the sense that new instrumental behavior is more readily associated with this modified stimulus pattern than it would have been to the pattern originally aroused by the end organ stimulation. As a consequence it is possible to make the association between the modified stimulus pattern and the instrumental behavior nonfunctional, as was done in this experiment by shifting the animals from the simultaneous to the successive dis-

crimination, and still obtain transfer effects. As long as the mediating process is aroused in the new situation by the physical stimuli with which it is associated, it will lead to faster learning of new instrumental behavior to these same cues as the relevant ones than would have been possible if this mediating process had not been established by previous learning.

These mediating processes are conceived of as having the characteristics of instrumental behavior, i.e., they are assumed to be learned, unlearned, and to show all the other functional properties that have been demonstrated for instrumental behavior. The fundamental assumptions underlying this formulation are as follows. (a) These processes are associated with external stimulus situations according to the same principles as govern the learning of other responses. (b) They can function in the capacity of a stimulus in the sense that other behavior can be associated with them. (c) They can equally well be overt or covert, peripheral or central.

The concept of acquired distinctiveness of stimuli implies that the mediating process associated with the physical stimuli during learning tends to be of such a nature as to facilitate the acquisition of the correct instrumental behavior. This assumption is reasonable in light of the general principles of reinforcement theories of learning. Any mediating process that tended to inhibit or slow up the learning process would result in an increased number of nonreinforced or punished trials. As a consequence this mediating process would tend to extinguish and would be replaced by some other mediating process. Any mediating process, on the other hand, that tended to facilitate the learning would result in an increased number of reinforced or rewarded trials. This would strengthen the association between the physical stimulus and the mediating process. In this way the mediating process would tend to enhance the distinctiveness of the relevant aspect of the stimulus situation.

The question remains, however, as to how readily any given aspect of the physical stimulus situation will acquire such distinctiveness. It seems probable that the *readiness* with which a mediating process is associated with a given physical stimulus is to a large extent determined by the nature of that stimulus, the context in which it occurs, and the innate makeup of the organism, but that the *degree* of distinctiveness obtained can be varied by the type of training involved.

In the present experiment the greatest transfer effect was always associated with black-white as the relevant stimulus, even though the rough-smooth and the wide-narrow groups were given the same training. This suggests that some stimulus aspects acquire distinctiveness more readily than others when the training conditions are constant. On the other hand, there is some evidence indicating that the extent to which any cue acquires distinctiveness is in part a function of the training procedure. Each of the 18 positive transfer animals was given two scores. The first score was the number of trials on which it made one or more errors on the T-maze when the relevant cue present was the same one that had been the positive cue for that animal in the simultaneous discrimination. The second score was the number of trials on which it made one or more errors when the relevant cue was the same as the negative cue for that animal in the simultaneous discrimination. The animals averaged 11.1 such trials on the positive cue and 8.9 such trials on the negative cue. The t-value for these correlated measures was significant between the one and five percent levels of confidence. While this difference is relatively slight, it suggests that the negative cue acquired greater distinctiveness than the positive cue, possibly because the mediating process associated with it was determined in part

by the punishment involved. Thus, the nature of the previous experience with a cue may be a determinant of the degree of distinctiveness acquired by that cue.

Summary

The present experiment was based on the hypothesis that previous experience of an *S* with various cues, irrespective of the instrumental behavior originally associated with them, is an important determinant of the rapidity of learning in a new situation involving the same cues. In order to test for this transfer effect and at the same time separate out the influence of previous experience with a cue from the influence of the instrumental behavior, the animals were first trained on a simultaneous discrimination and then tested on a successive discrimination. The assumption was that the instrumental responses learned in one situation would neither facilitate nor hinder the learning of new instrumental responses in the second; any transfer obtained would have to be attributed to previous familiarity with the stimuli employed.

A third of the 54 albino rats were trained in the simultaneous discrimination on one of the three different stimulus dimensions used; black-white, rough-smooth floors, and wide-narrow goal compartments. The successive discrimination always contained two sets of these cues, a relevant one and an irrelevant one. The relevant cue was the one on which the discrimination was based, i.e., it was correlated with the rewards; the irrelevant cue was not correlated with the reward but was paired with the relevant cue in a random manner. The 'positive' transfer animals had the same cue in the simultaneous discrimination as the relevant one in the successive discrimination; the 'negative' transfer animals had the same cue in the simultaneous as the irrelevant in the successive; and the 'control' animals had a different cue in the simultaneous from either of the two cues in the successive discrimination.

1. It was found that the positive transfer animals, who were familiar with the relevant cue, learned the successive discrimination significantly more rapidly than did either the negative transfer or the control animals.

2. No significant differences were found in the learning rates of the negative transfer animals and the control animals. There was a possibility that the learning of the control animals was retarded because of external inhibition. Consequently, the direction of the transfer effect in this experiment could not be determined.

3. The explanation offered of this transfer on the basis of familiarity with a cue was in terms of the acquired distinctiveness of cues. It was assumed that a mediating process was established during the simultaneous discrimination training that tended to enhance the distinctiveness of the relevant cue. This mediating process transferred to the successive discrimination. As a result of this enhanced distinctiveness of the relevant cue in the test situation, new instrumental responses were associated with this familiar cue more rapidly than with the unfamiliar one. The implications of this hypothesis for a theory of discrimination learning were discussed.

At the completion of the successive discrimination training, all animals were retrained on a simultaneous discrimination involving a relevant and an irrelevant cue. The above findings

were confirmed and given increased generality in that this indicated that they were not specific to any one test situation.

(Manuscript received January 4, 1949)

References

1. Grice, G. R. The relation of secondary reinforcement to delayed reward in visual discrimination learning. *J. exp. Psychol.*, 1948, **38**, 1–16.
2. Hull, C. L. Knowledge and purpose as habit mechanisms. *Psychol. Rev.*, 1930, **37**, 511–525.
3. Köhler, W. Intelligence in Apes. In: *Psychologies of 1925*. Worcester, Mass.: Clark Univ. Press, 1925.
4. Koffka, K. *The growth of the mind*. London: Kegan Paul, Trench, Trubner Co., Ltd., 1928, pp. 189–191.
5. Krechevsky, I. An experimental investigation of the principle of proximity in the visual perception of the rat *J. exp. Psychol.*, 1938, **22**, 497–523.
6. Leeper, R. A study of a neglected portion of the field of learning—the development of sensory organization. *J. genet. Psychol.*, 1935, **46**, 41–75.
7. May, M. A. Experimentally acquired drives. *J. exp. Psychol.*, 1948, **38**, 66–77.
8. Miller, N. E. Studies of fear as an acquirable drive: I. Fear as motivation and fear-reduction as reinforcement in the learning of new responses. *J. exp. Psychol.*, 1948, **38**, 89–101.
9. Miller, N. E., & Dollard, J. *Social learning and imitation*. New Haven: Yale Univ. Press, 1941. Chap. V.
10. Snedecor, G. W. *Statistical methods*. Ames, Iowa: The Iowa State College Press, 1946.
11. Spence, K. W. Continuous versus noncontinuous interpretations of discrimination learning. *Psychol. Rev.*, 1940, **47**, 271–288.
12. Tolman, E. C. Determiners of behavior at a choice point. *Psychol. Rev.*, 1938, **45**, 1–34.

SELECTIVE ASSOCIATION AND THE ANTICIPATORY GOAL RESPONSE MECHANISM AS EXPLANATORY CONCEPTS IN LEARNING THEORY [1]

BY ABRAM AMSEL [2]

From the Psychological Laboratory, University of Iowa

INTRODUCTION

Background of the Problem

The concept *drive stimulus* (S_D) is one which has become increasingly important for behavior scientists. In Hull's systematic formulation (8), it is defined as the stimulation arising from a condition of need or motivation. As a stimulus, S_D is a component of the total stimulus complex and, as such, has the capacity to acquire habit loading like other (external) stimuli.

Recently, an hypothesis has been stated which would differentiate two classes of drive stimuli with respect to their role in learning. The basis of the distinction is whether or not the need with which the stimulus is associated is the one which is rewarded in the learning situation. This hypothesis of selective association, as it is called, has been suggested by Kendler (10) to explain certain of his experimental findings. Thus, he found that after rats, which were both hungry *and* thirsty, had been run in a T-maze in which one arm led to food and the other to water, they were subsequently able to respond to the appropriate side when either hungry or thirsty. Kendler suggested that these experimental findings were "consistent with a principle of association which stated that only those drive stimuli which are themselves reduced become connected to a rewarded response." He reasoned that if one does not postulate such a selective factor to be operating in the associative mechanism, then the hunger drive stimulus should be as strongly conditioned to the response of choosing the water side as to the response leading to the food alley, and there should be no greater likelihood of making the response to food, when hungry, than of making the response leading to water.

In terms of the selective association hypothesis offered by Kendler, it would seem necessary to differentiate between the two aspects of relevant and irrelevant needs and their influence upon responses.[3] Relevant needs, according to such a formulation, are, in addition to being activators of response, associated with drive stimuli which become conditioned to the rewarded response. Irrelevant needs, while they serve to activate responses (14), have associated with them drive stimuli which do not become connected to responses. In terms of the above stated hypothesis, then, relevant needs influence responses through associative as well as non-associative channels; irrelevant

[1] This paper is a portion of dissertation submitted to the Department of Psychology of the State University of Iowa in partial fulfillment of the requirements for the degree of Doctor of Philosophy. The writer is indebted to Professor Kenneth W. Spence for advice and assistance through all phases of the investigation.

[2] Now at Newcomb College, Tulane University.

[3] *Relevant* needs are defined as those need states which are reduced by the response being studied in a given situation; *irrelevant* needs are those need states, which may coexist with the relevant need, but which are not themselves reduced by the response in question.

needs influence responses only as a non-associative factor.

There is, as Kendler recognizes, another explanation for his results within the framework of reinforcement theory. This explanation, suggested by Spence (12), invokes the fractional anticipatory goal response mechanism which Hull first postulated to explain certain phenomena of complex maze learning (4, 5, 6). In terms of the anticipatory goal response (r_g–s_g) mechanism, the explanation of the results is, to quote Kendler, as follows:

> . . . the stimuli in the food box and in the alley leading to the food box become associated with anticipatory eating responses (salivation, mascitory movements, etc.) and, in turn, the proprioceptive stimulus components resulting from these anticipatory goal responses become themselves conditioned to entering and continuing locomotion in the alley leading to the food box. In a similar manner anticipatory drinking responses become conditioned to the alley leading to water and provide cues which tend to elicit the response of approaching and continuing locomotion in that alley.

And further:

> During the test series when only a single drive is present, for example hunger, . . . [the] reason that the anticipatory food responses are dominant over the anticipatory drinking responses . . . is that in the previous history of the animal the hunger drive has acquired a strong tendency to elicit eating responses and only little, if any, tendency to evoke drinking responses.

Finally, as Kendler points out, Tolman's theory of learning would have no difficulty explaining the results of this experiment. Tolman's explanation would be that during the initial training period the animal acquires cognitions about the locus of food and water in the maze, i.e., that one set of stimulus events followed by one pattern of behavior (left turn) leads to water. During the test trials, then, the animal responds appropriately to the motivation with which it is provided.

While it is conceivable that all three of the mechanisms postulated by the above formulations may be operating in this experimental situation, it would be parsimonious to try, if possible, to eliminate one or more of the suggested explanations by means of a critical experimental test.

One test of Kendler's hypothesis of selective association would involve an experimental situation in which learning could result only from the presence of differential irrelevant drive stimuli. The present study makes use of this type of experiment. Essentially, it consists of training white rats in a T-maze, the incentive or goal object being escape from certain anxiety-inducing stimuli in the maze. Since the two goal boxes are identical, two alternative anxiety-reducing responses (left and right turning) are possible. On any one trial, however, only one of the responses leads to the goal object; the other results in failure to escape from the anxiety-inducing situation. The subjects are required to make a differential response (choose one of the two alternative paths) on the basis of which of the two irrelevant needs is present at the time.

The experimental situation described above may be compared with one employed independently by both Hull (7) and Leeper (11). The experiment, in each case, was designed to ascertain whether, in a two-choice situation, white rats can learn to make one response (e.g., left) when hungry to obtain food, and another (e.g., right) when thirsty to obtain water. The essential experimental differences between the Hull-Leeper experiment and that which has been outlined here are: (1) in the Hull-Leeper type of design, the reinforcement for each response is relevant to the motivational condition (drive stimulus) to

which that response is being conditioned, while in the one proposed here the reinforcement is always irrelevant to the two needs which provide for the differential stimulation; and (2) in the former there is differential reward (the reward for alternative responses is not the same), while in the latter there is not differential reward (anxiety reduction rewards both of the responses).

The experimental differences indicated can be shown to have definite implications with respect to the possible operation of the fractional anticipatory goal response mechanism in the two experimental situations that have been delineated. Since the r_g–s_g mechanism, as it has been described earlier, is dependent upon the nature of the goal object (e.g., anticipatory drinking responses when water is the goal object; anticipatory eating responses when food is the goal object), then it is clear that in the Hull-Leeper experiment the operation of differential r_g–s_g's would presumably facilitate the learning of a two-choice problem, where thirst and hunger are the differential stimuli on which the discrimination is based. In the experiment here described, the same goal object (anxiety-reduction) reinforces both responses. If the r_g–s_g mechanism is operating here, it cannot, therefore, result in a differential facilitating effect, since any anticipatory goal responses which are conditioned to stimuli in the alleys of the maze must be based upon some consummatory response which accompanies anxiety reduction, and the proprioceptive stimuli from such anticipatory responses would, presumably, be equally strongly conditioned to both the right-turning and the left-turning responses in the T-maze.

Statement of the Problem

The present investigation provides two experimental situations, the first being one in which the only differentiating stimuli in a spatial discrimination setup are irrelevant (non-reduced) drive stimuli, one resulting from food deprivation and the other from water deprivation. If, in this situation, the discrimination can be learned, then the hypothesis of selective association, proposed by Kendler, is disproved. The experimental situation is also one in which the two alternative responses are reinforced by the same goal object. For this reason, differential fractional anticipatory goal responses cannot be operating here to facilitate learning. When, however, the alternative responses (turning left and turning right in the T-maze) are reinforced differentially (food for one, water for the other), then differential fractional anticipatory goal responses can, presumably, be operating as a mechanism to facilitate learning. This latter is a statement of the second experimental condition.

If there is failure to learn on the basis of irrelevant drive stimuli, then Kendler's hypothesis cannot be rejected. An hypothesis which states that selective learning depends upon the presence of differential anticipatory goal responses would also then be tenable. If some learning is shown on the basis of irrelevant drive stimuli, then a large difference in the rate or limit of learning between the two experimental conditions could be taken as an indication of the effect of the r_g–s_g mechanism in selective learning.

Preliminary Experiment

A preliminary experiment was designed to ascertain whether a spatial discrimination (T-maze) could be learned on the basis of a

secondary (anxiety) drive and secondary drive reduction.

The apparatus employed in this investigatory study was the same as that used in the main portion of the experiment (see Apparatus section) with one modification: the T-maze, described as apparatus B, had one white and one black goal box instead of two black goal boxes as in the main experiment.

Ten male albino rats were subjects for this experiment. For four successive days, each *S* was run a single trial in Apparatus A. The procedure on each trial was a follows: (1) *S* was placed in the starting box of the apparatus, (2) a shock of 75 microamps was administered as the starting-box door was raised, (3) the animal was allowed to escape the shock by entering the black goal box through a swinging door. This procedure was designed to condition an anxiety drive in the *S*s to the stimulation from the white apparatus and the grid floor.

After this anxiety acquisition training, the *S*s were run for nine successive days in the single-choice T-maze with the grid-floored starting box and alleys, one black goal box and one white goal box with wooden floors. No shock was used in this part of the experiment. Four trials were run on each of the nine days, two free and two forced in order to equalize the experience with black and white goal boxes.

Fig. 1 shows a curve which represents the acquisition of response to the black-goal-box side by the 10 animals. Percent response to that side on the first trial on each day is plotted over the nine-day period. The data reveal that by the sixth day, response to the black-goal-box side was up to 90 percent. On the first trial in this series, on the first day, the response to that side had been 30 percent. The falling off after day six of this series can probably be attributed to the fact that the anxiety drive was not reinforced by shock during the nine-day series.

This preliminary experiment indi-

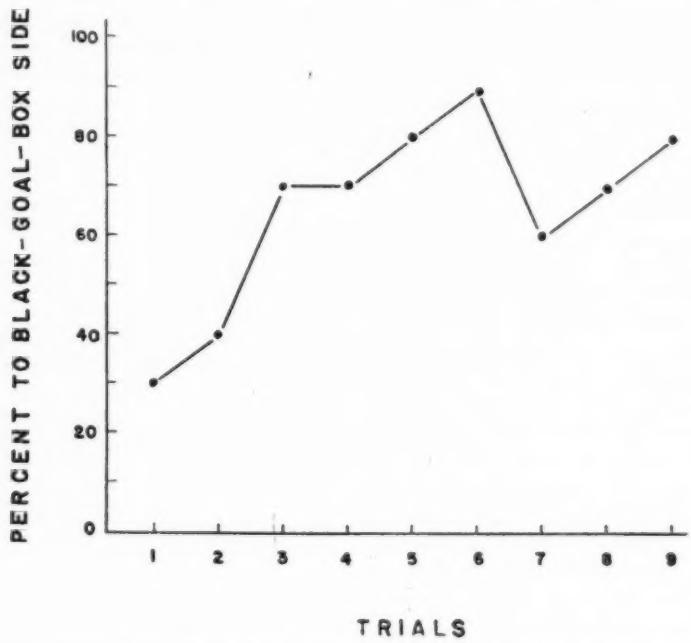


Fig. 1. Curve showing learning of the response leading to the anxiety-reducing goal box. Drawn from first-trial runs on nine successive days. (N = 10.)

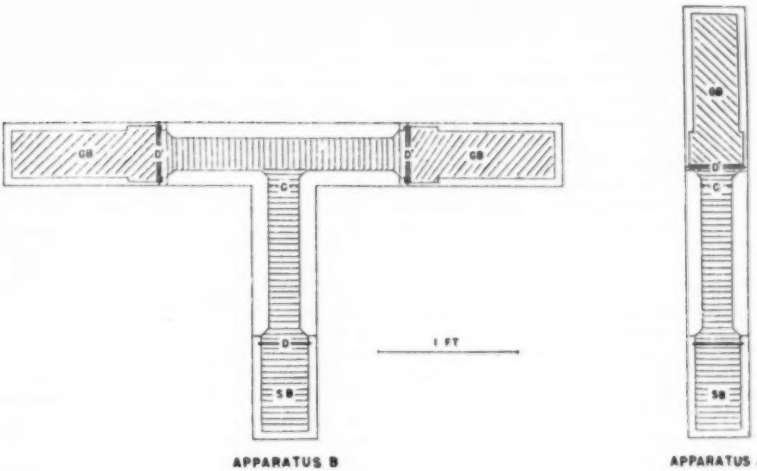


FIG. 2. Ground plan of apparatus A and apparatus B. SB—starting box; D—guillotine door; D—swinging door; C—curtain; GB—black goal box. Horizontal and vertical lines show portions of apparatus with grid floor.

cated that anxiety and anxiety-reduction are adequate drive-reinforcement conditions for the acquisition of a spatial discrimination. Since, in the main portion of this experiment, the animals are required to make a response to the right to escape anxiety when hungry and one to the left to escape anxiety when thirsty, it is important to establish in advance that this motivation-reinforcement condition is adequate for learning, so that any possible failure of differential response to occur cannot be attributed to that factor.

EXPERIMENTAL PROCEDURE

Subjects

The subjects were 20 male hooded rats from the colony maintained by the Department of Psychology of the State University of Iowa. All had served as subjects in a previous experiment (1), and were between 85 and 115 days old at the start of the present experiment. The service of these *S*s in the previous experiment in no way affected their use in this experiment, since in that experiment the *S*s had run only in a straight runway which involved no differential spatial responses. Their prior service can, in fact, be regarded as a preparation for this experiment since it had served to condition an anxiety response to a white apparatus with a grid floor. In the present experiment, this anxiety response was maintained throughout, and determined the relevant motivational condition.

Apparatus

The entire apparatus consisted of two parts, one in which the secondary (anxiety) drive was maintained, and the other, a T-maze, in which the spatial discrimination training was carried out.

The first part of the apparatus, which will be called Apparatus A, is shown in Fig. 2. It consisted of a white starting box, with a grid floor 7½ in. long and 4 in. wide, a straight, white runway also with a grid floor 13 in. long and 2½ in. wide, and a black goal box with a wooden floor 13 in. long and 4 in. wide. The starting box and runway were separated by a guillotine door which could be raised and lowered by the experimenter. The runway and goal box were separated by a swinging door which opened into the goal box but not in the reverse direction. A curtain was placed in the runway 4 in. from the swinging door. This was done to make the stimulating conditions the same in this apparatus as in the stem of the T-maze, which will be described below. The starting box and runway were covered with plexiglas to prevent avoidance of

shock on the part of the *Ss* through clinging to the top of the apparatus. The goal box was covered with wire mesh.

The second part of the apparatus, which will be called Apparatus B, is also represented in Fig. 2. It included the starting box and the runway of Apparatus A, which became the stem of a single-choice T-maze. The alleys to the right and left of the stem had grid floors and the walls were painted white. Each was 8 in. long and 2½ in. wide, and was covered with plexiglas. At the end of each alley a black goal box was located. These were identical in size and structure with that in Apparatus A. At the entrance to each goal box was a swinging door like the one described above.

Illumination was provided by a 10-watt bulb which was suspended 4 ft. above the apparatus and directly above the choice point of the T-maze. Another 7½-watt bulb was situated 9 in. above the apparatus at a point half way down the stem of the T, which corresponded to a point half way down the straight runway when Apparatus A was in use. Illumination from this latter light source was controlled by the experimenter by means of a telegraph key type contact.

Shock was produced, when necessary, with a shock circuit which has previously been described (2).

Procedure

The *Ss* were divided into two groups, I and II, of 10 each: Group I animals were trained in the T-maze with irrelevant drive stimuli as the basis for discrimination; Group II animals were trained to discriminate on the basis of relevant drive stimuli.

The procedure on the first experimental day was intended to strengthen the anxiety response in the *Ss* to the stimuli arising from the alleys of Apparatus 2 (the T-maze). This response was already present to some extent due to their training in the previous experiment. Throughout the experiment the animals were run in Apparatus A with shock for this purpose. On day one, therefore, each *S* was run five trials in Apparatus A. The procedure on each run was as follows: *S* was placed in the starting box of the apparatus and five sec. were allowed to elapse; then the light directly above the runway was turned on, and after three sec., the door of the starting box was raised with a sharp sound. Immediately following the raising of the door (about .25 sec.) the grid was activated with a current of 75 microamps.[4] The animal was allowed to escape the shock by pushing through the swinging door into the black goal box. It was allowed to remain in the goal box for 30 sec., and was then returned to the carrying cage.

One each day after the first the procedure was identical except for changes in the motivational conditions within the groups. Each day's run for each animal consisted of five trials in Apparatus B, i.e., training on the spatial discrimination, and one trial in Apparatus A to maintain the anxiety drive. On any trial in Apparatus A the procedure was the same as that followed on the first day of training. The procedure followed during a single run in Apparatus B was as similar as possible to that used when Apparatus A was employed, except that no shock was ever introduced in Apparatus B.

No difficulty was encountered keeping the animals running in the T maze. Throughout the experiment, the anxiety drive maintained a running response which was directed toward entrance of one or the other of the black goal boxes.

All of the stimulating conditions, including the to-be-discriminated hunger and thirst stimuli, were kept as identical as possible in Groups I and II. The drive stimuli, both thirst and hunger, were due to 21–24 hr. of food or water deprivation.[5] The details of the maintenance schedule for hunger and thirst days were as follows:

Thirst days: If the previous day had been a hunger day, *S* was given nine gm. of Purina dog chow 30 min. after that day's run. After feeding, *S* was allowed to drink until it turned away from the water bottle. From this time until the next day's run *S* was deprived of water. On thirst days, the daily ration of food was given prior to the experimental session. Half of the nine gm. was given approximately four hr. before the day's run; the other half of the ration was given an hour before the *S* was to run under thirst stimulation.

Hunger days: *S* was deprived of food from the previous day's feeding until after the hunger

[4] A current of 75 microamps was used on the first day. During the remainder of the experiment, when one trial per day was run in Apparatus A, the shock strength was gradually raised to a value of about 175 microamps in an attempt to compensate for adaptation effects.

[5] It was impossible to maintain exactly the same deprivation schedule throughout due to the nature of the experiment. For instance, if an animal ran under a hunger drive one day and under the same drive on the next, then approximately 21 hr. elapsed between feeding after hunger day one and running on hunger day two. If, however, the animal ran under thirst on one day and hunger the next, then the animal would be fed immediately before the thirst run and 24 hr. would lie between this feeding and the hunger run on the next day.

trials on that day. To insure that no appreciable thirst drive was operating on hunger days, *S* was also deprived of water between approximately the fourteenth and fourth hours before the day's runs, i.e., the water bottles were removed from the cages approximately 14 hr. before the hunger runs and reinserted four hr. before the trials on that day. It was felt that this procedure might insure that the *S*s would drink more water immediately preceding the hunger runs, so that a minimal thirst drive would be operating.

On any given day of the experimental sequence, half the *S*s were run under thirst and half under hunger. Conditions were also arranged so that half of the *S*s escaped anxiety by entering the right black goal box when hungry and left when thirsty, and for the other half the reverse conditions held.

The *S*s of Group I were allowed to remain in the goal box for 30 sec. following each entrance. Since a correction technique was employed, every trial ended with entrance into the goal box. If *S* running under hunger made the response which was correct, under thirst, the swinging door into the goal box on that side was barred, and *S* had to turn around and enter the alley on the opposite side to escape anxiety.

The *S*s of Group II went through the same procedure with one exception. In addition to escape from anxiety as a reward for the correct response on any given day, the animals of this group were given a very small quantity of food (approximately .08 gm.) or water (10 sec. of drinking) in the black goal box. The time taken to eat the food was about 20 sec.

The pattern of hunger and thirst days in the total experimental sequence was largely single alternation.[6] To insure that a single alternation pattern was not being learned, the drive condition of one day was occasionally duplicated on the next.

The individual criterion of learning was 10 successive correct first-trial responses. When an animal reached this level of performance, its service in this part of the experiment was discontinued and the remainder of its trials were assumed to be correct.[7]

After the animals of Group II had reached the criterion of 100 percent correct response, the experimental conditions for these animals were changed by the omission of the differential food and water reward. During the succeeding trials, in other words, the Group II *S*s ran under the same conditions as the Group I *S*s. Each of the *S*s in Group II was run 30 days under these conditions.

Results

The number of trials taken by the *S*s in Groups I and II to reach the criterion of learning (10 successive correct first trials) is indicated in Table I. A score of 450+, for instance, means that the training of a subject was discontinued at the 450th trial and that the *S* had not yet reached the criterion at this stage. As shown in the table, all of the *S*s in

TABLE I

Number of Trials to Reach the Criterion

Group I		Group II	
Number of *S*	No. Trials	Number of *S*	No. Trails
3	450+*	1	80
4	450+	2	255
6	450+	5	70
7	450+	8	120
9	450+	10	215
11	350	12	125
13	495	14	165
15	540+	17	70
16	540+	18	180
20	540+	19	40

* These 450+ scores are made up to 78 days running 5 trials per day, and 30 days of running 2 trials per day. Numbers 3, 4, 6, 7, and 9 followed this procedure, the remaining *S*s ran 5 trials per day throughout.

[6] In a somewhat similar experiment, Hull (7) used single alternation throughout. With animals running under conditions comparable to Group II of the present study, 240 days of five trials per day were taken to reach 85 percent correct choice. This would indicate that there is little, if any, ability in white rats to learn a single alternation pattern of response on a basis of 24 hours between alternative responses, especially since five trials are given on each day and only the first trial per day is considered.

[7] To test this assumption, two of the Group II animals were run beyond their criterion trials. Out of 30 additional first trials run by these two *S*s, only one error was recorded. The assumption that the *S*s *in Group II* performed 100 percent beyond 10 successive correct trials seemed to be a good one on the basis of the sample of runs observed.

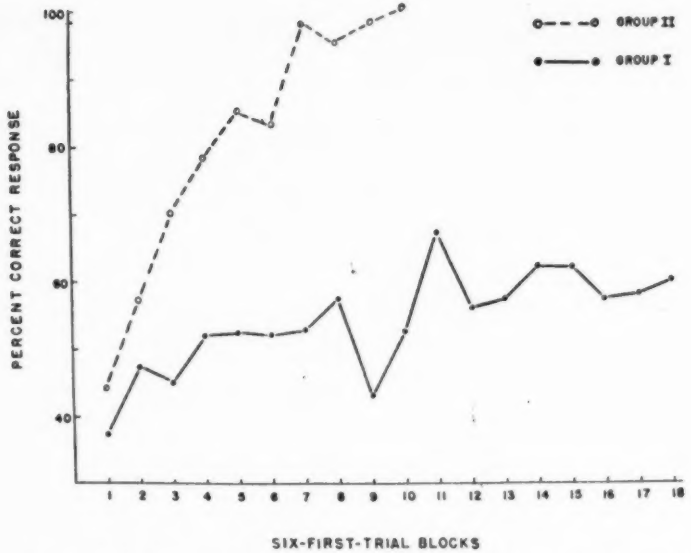


FIG. 3. Learning curves of the two different groups. (N = 10 for each curve.)

Group II reached the criterion, the last to reach it doing so at the 255th trial (i.e., after the 51st day of the training series), and the first at the 40th trial. Within the number of trials run, only two of the Group I subjects reached the criterion, one on the 350th trial and the other on the 495th trial. The remaining eight *S*s of Group I failed to reach the criterion established prior to the running of the experiment.

A graphic comparison of group performances is given in Fig. 3. This shows the percentage of correct responses of the two groups for successive blocks of six first trials. Each point is, therefore, the percentage of correct responses out of the possible 60 in a block. It is evident from an examination of the curves that a very great difference exists between the performances of Group I and Group II. The Group I curve reaches the 100 percent correct response level by the tenth six-first-trial block, while the Group I curve appears to have leveled off at about 60 percent correct response by the 14th block of trials.

Insofar as the present experiment is a test of Kendler's hypotheses of selective association, it is necessary to determine whether or not any of the Group I *S*s which had to learn on the basis of the differential irrelevant drive stimuli actually did learn to respond appropriately. For this reason the data of this group were further analyzed in terms of individual animal performance. The 108 daily first trials of each *S* of Group I[8] were

[8] The criterial runs of one of the *S*s, No. 1, were completed by the 80th day. This animal was run with the others in Group I for the full 108 days. Of the 28 first trials, between the 80th and the 108th days, it ran 21 correct. Although this is substantially better than chance performance, it does not warrant the same assumption that was made in the case of the Group II *S*s: that after 10 successive correct first trials, a *S* would continue to run 100 percent correct. The second of the Group II *S*s to reach the criterion actually ran the last criterial trial on the 109th day.

divided into three parts, i.e., first 36 first trials, second 36 first trials, and last 36 first trials. The number of correct responses within each of the 36-trial blocks was computed for each *S*. This information is summarized in Table II. An examination of this table will reveal that within the first block of trials (days 1–36), only one *S* ran more correct first trials than would be expected by chance (18 being chance expectation where $P = .5$), in the second block six *S*s exceeded chance expectation, and in the last block seven *S*s exceeded that number. It will be observed that the two *S*s of Group I which reached the criterion of learning (nos. 11 and 13) performed in a chance manner on the first block of trials, and performed more correctly than chance on the next two blocks, running 29 and 26 correct respectively out of the last 36 trials.

TABLE II

NUMBER OF CORRECT RESPONSES

Number of *S*	Trials 1 to 36	Trials 37–72	Trials 13–108
3	16	24	22
4	19	21	18
6	18	19	19
7	16	18	20
9	18	14	16
11	18	21	29
13	18	20	26
15	17	17	20
16	16	25	26
20	15	18	17

The use of the normal approximation formula for the binomial distribution[9] indicated that a deviation as large as six, from the expected 18 correct out of 36, would be significant at the five percent level of confidence, that a deviation of eight would be significant at the one percent level of confidence, and that a deviation of ten (or more) would be significant at the 0.1 percent level of confidence. An examination of Table II will reveal that in no case is a negative deviation from 18 (fewer correct than 18) significantly different from chance expectation (at the five percent level of confidence). There are, however, several deviations in the positive direction which have statistical significance. The largest deviations from chance expectation occur in the third block of trials (the last 36 days). Subject 11 ran eleven more correct trials than the expected 18; and subjects 13 and 16 ran eight more than the expected number of correct trials on the basis of a probability of .5 for the correct response. The level of confidence at which an hypothesis of chance performance can be rejected is: 0.1 percent for subject 11, and one percent for subjects 13 and 16. It will be recalled that subjects 11 and 13 were the ones which reached the preestablished criterion of learning. On the second block of 36 trials the performance of two *S*s (nos. 3 and 16) exceeded chance expectation at the five percent level of confidence.

The same analysis was made of individual animal performance over all 108 first trials ($n = 108$). According to this analysis the three *S*s showing best performance were nos. 11, 13, and 16. The performance of subject 11 was better than chance at the one percent level of confidence, that of subject 16 at the two percent level,

[9] The normal deviate is computed from the formula:

$$\frac{X}{\sigma} = \frac{m - np}{\sqrt{npq}},$$

where m is the number of correct responses, n is the total number of responses, and p and q are the theoretical probabilities of correct and incorrect responses (.5 in this case). Grant (3) indicates that this approximation may safely be used when $n = 30$ and when p and q do not deviate considerably from .5.

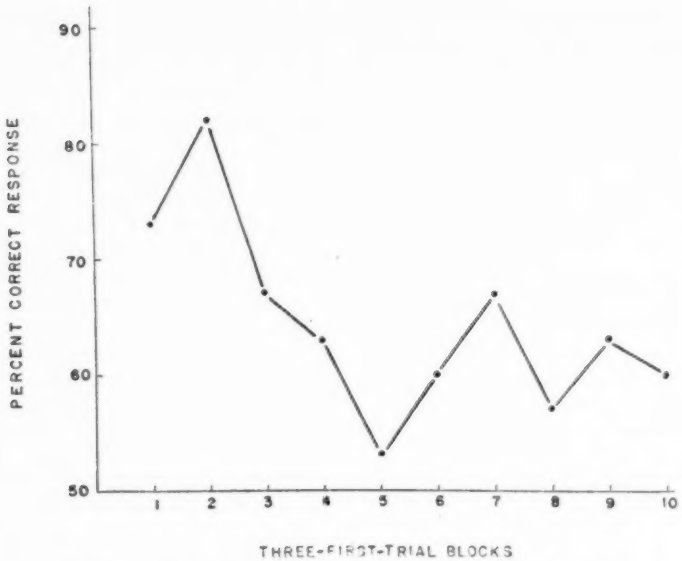


FIG. 4. Performance of Group II subjects over the 30-day period following removal of the differential rewards. (N = 10.)

and that of subject 13 at the six percent level.

In Fig. 4 is represented the performance of the 10 Ss of Group II on the 30 days following the removal of the food and water reinforcement for the two alternative responses. The anxiety-reduction reinforcement remained, as in Group I. This change in the procedure was introduced for each S after it had attained 100 percent performance. Fig. 4 shows percent correct response plotted against successive blocks of three first trials, so that each point represents a percentage computed on the basis of a possible 30 correct responses. It will be observed that the first point on the curve is lower than the second. This may be due to some immediate frustration effect resulting from the removal of the differential reward which had been present during all of the preceding trials. The curve drops very sharply to a performance level of 53 percent on the fifth three-trial block, and then levels off at about 60 percent performance (correct response). It will be recalled that this was approximately the level of performance which was attained by Group I.

DISCUSSION OF RESULTS

Kendler's hypothesis of selective association states, in effect, that irrelevant drive stimuli do not become associated with rewarded responses with which they are contiguous. The performance of the Ss in Group I of the present experiment makes the tenability of such an hypothesis questionable. According to a preestablished criterion of learning (10 successive correct first trials), two of the 10 Ss of this group learned the spatial discrimination on the basis of

differential irrelevant drive stimuli arising from hunger and thirst needs; one other of the 10 *S*s exhibited a greater number of correct responses than could be attributed to chance, although the criterion was not reached by this *S* during the trials run. Considering the performance of the Group I *S*s alone, one might, therefore, be led to modify Kendler's hypothesis thus: irrelevant drive stimuli (of the hunger and thirst type) become connected to rewarded responses with which they are contiguous only as the result of considerable practice.

There is some basis, other than that provided by the present investigation, for a statement such as the above. This derives from a characteristic of hunger and thirst drive stimuli (and many other drive stimuli) which seems to have been heretofore neglected, namely, that such stimuli are not of the type which are 'set on' in an experimental situation. Such stimuli must be considered as having already been present for a considerable period of time when the animal is brought into the experiment and hence when the response in that situation occurs. Hull (**8**, p. 207) has made the following statement about stimuli of this sort: ". . . it is probable that static, i.e., unchanging elements or aggregates in a conditioned stimulus situation are considerably less potent in the acquisition of habit-strength loadings than are the more dynamic, i.e., the changing elements or aggregates." A study by Kappauf and Schlosberg (**9**) has shown that strength of conditioning is some inverse function of the time by which the conditioned stimulus precedes the unconditioned stimulus (or the response). In terms of these considerations, then, it is not unlikely that drive stimuli, of the type produced by food and water deprivation, are stimuli which acquire habit loadings very slowly.

As a matter of fact, relevant as well as irrelevant drive stimuli, of the kind indicated, should acquire habit loading only with great difficulty, according to the above formulation, since both are stimuli which have been acting over a long period of time when the response in question occurs. If we accept such a notion as plausible, it still remains to account for the results of the present experiment: that the Group II *S*s, provided with differential *relevant* drive stimuli, learned very much more completely and quickly than the Group I *S*s which were provided with differential *irrelevant* drive stimuli. It is recognized that the additional reinforcement for the Group II *S*s (from the differential food and water rewards) might explain some difference between the groups, in terms of amount of reinforcement alone. It is believed, however, that such a difference as was shown here cannot be accounted for solely in these terms.

Since the stimulating conditions at the start of training were identical in both groups, a possible explanation of the difference in behavior which developed between the two groups would be in terms of some additional differential stimulating factor which the Group II *S*s *acquired during the training procedure* and which the Group I *S*s did not. Such a factor would result from the differential reinforcement (food for one response, water for the other) which was provided the *S*s of Group II, and not those of Group I.

Because, in the T-maze situation, the Group II *S*s were rewarded by a small amount of food for the correct response when hungry, and by a small amount of water for the opposite response when thirsty (in addition to

anxiety reduction), two different goal responses occurred in the two goal boxes of the maze, i.e., eating in one and drinking in the other. There are, therefore, present the necessary conditions for the conditioning of two kinds of fractional anticipatory goal response (r_g) to the maze alleys. Following the description given by Spence (13) of the acquisition of this mechanism, the stimuli in the goal box containing water and in the alley leading to this goal box become conditioned to anticipatory drinking responses (r_{gd}), and those in the goal box containing food and in the alley leading to the food box become conditioned to anticipatory eating responses (r_{ge}). The proprioceptive stimuli arising from these anticipatory acts (s_{gd} and s_{ge}) then become differential stimuli in the learning of the maze. One (s_{gd}) becomes conditioned to entering and continuing locomotion in the alley leading to water; the other (s_{ge}) becomes, in the same manner, conditioned to the responses leading to food. Such differential stimuli are not operating in the case of the Group I *S*s, since, in this group, if the r_g–s_g mechanism is present it cannot be differential with respect to the two alternative responses, i.e., there is, here, only one kind of reward, anxiety-reduction, and any anticipatory response based upon this reward would result in an s_g which must become equally conditioned to both the left and right turning responses.

If stimulation arising from the apparatus becomes conditioned to both anticipatory eating and anticipatory drinking responses (in the Group II *S*s), it remains to show how, on any particular trial, *S* comes to choose the correct path, i.e., that leading to the goal object for which it is motivated. This choice depends upon the motivational conditions of the animal: if *S* has been deprived of food, then anticipatory eating responses are relevant to the motivational condition and anticipatory drinking responses are not. Consequently, the eating r_g should be more intense than the drinking r_g and, therefore, the eating s_g more intense than the drinking s_g. The path chosen is then the one which has previously been conditioned to the s_g which is dominant at the moment. To the extent that the drive stimuli associated with the relevant motivation can become connected to the appropriate response, this would also determine the path chosen on that trial. We have suggested, however, that the kind of drive stimuli involved here do not acquire a great amount of habit loading.

A diagrammatic representation of the learning factors which determine the performance of Groups I and II is presented in Fig. 5. In the case of the Group I *S*s, the occurrence of the correct response (e.g., right when hungry) must be due to the differential component of habit strength (H) contributed by the drive stimulus, S_{DH}, since the stimuli in the maze (S_A) have become conditioned to both right and left-turning responses. The presence of these apparatus stimuli which are conditioned to both responses would, in fact, make the spatial discrimination more difficult for the Group I *S*s. In the case of the Group II *S*s, differential stimulation and, therefore, differential habit loading comes from two sources: (1) from the drive stimulus present (as in Group I); and (2) from the proprioceptive stimulus (s_g) relevant to the motivational condition of the animal on that particular day.

Returning now to the earlier part

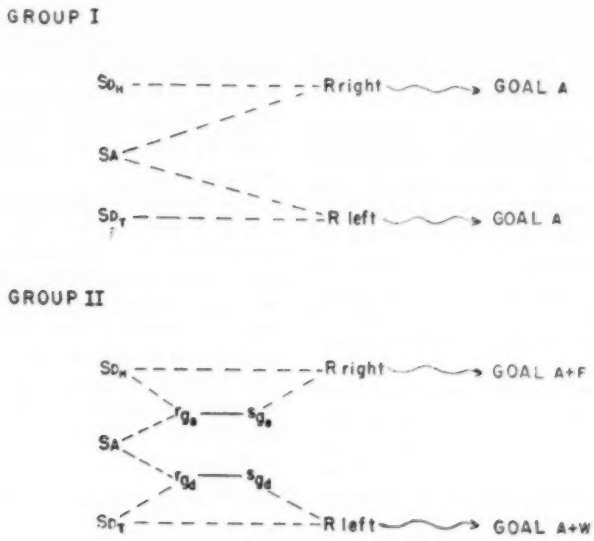


FIG. 5. Diagrammatic representation of factors influencing the learning of the two groups. S_{DH}—hunger drive stimulus; S_{DT}—thirst drive stimulus; S_A—stimuli from apparatus; r_{ge} and r_{gd}—fractional anticipatory components of eating and drinking responses; s_{ge} and s_{gd}—stimulation arising from the anticipatory responses; *A*—anxiety reduction; *F*—food; *W*—water.

of the present discussion, it will be recalled that to the hunger and thirst drive stimuli, because of their persistent characteristic, was attributed a reduced capacity to acquire habit loading. This is not the case, however, with the stimulation arising from the fractional anticipatory goal reactions. This stimulation has its onset immediately preceding the response to which it is conditioned. It is the addition of this differential stimulus factor (the addition of the r_g–s_g mechanism) which is here put forth to account for the extreme difference in the rate (and perhaps the limit) of learning between Groups I and II found in the present experiment.

The data shown in Fig. 4 lend support to the above interpretations. As is indicated there, when the differential rewards (food and water) for the responses of the *S*s in Group II were removed, the performance of these animals dropped from a level of 100 percent to a level of approximately 60 percent. The present formulation would suggest that the removal of these rewards, leaving the anxiety-reduction reward for both responses (left and right) as in Group I, resulted in the extinction of the differential fractional anticipatory goal responses, and so the removal of the differential proprioceptive stimuli (s_{ge} and s_{gd}) from the stimulus complex. There would, thus, remain as differential stimuli only the hunger and thirst drive stimuli, as in Group I. It may, therefore, be somewhat more than coincidental that this curve appears to level off at about 60 percent correct response, which was about the level of

performance achieved by the Group I subject.

Summary

The present experiment attempted to evaluate an hypothesis of selective association—that drive stimuli, not themselves reduced by a goal object, do not become connected to the rewarded responses with which they are contiguous—and the fractional anticipatory goal response mechanism of Hull as explanatory devices in learning theory.

Two experimental situations were involved. The first served to test the selective association hypothesis, and involved the learning of a T-maze on the basis of discrimination between two irrelevant drive stimuli, one resulting from food deprivation, the other from deprivation of water. Both responses (left and right turning) were rewarded in the same manner, by anxiety reduction. Insofar as some of the subjects learned in this situation, the selective association hypothesis was not supported.

The second experimental situation involved the learning of the same discrimination on the basis of the same drive stimuli, which were now, however, relevant in the sense that a correct response under thirst stimulation was rewarded with water, while a correct response when hungry was rewarded with food (in addition to the anxiety reduction of the first situation). It was indicated that this situation differed from the first in that here there was the possibility for differential fractional anticipatory goal responses, which would facilitate learning, while in the first situation there was not this possibility.

When two groups, of 10 white rats each, were run under the two experimental conditions described, a very considerable difference in the rate of learning was shown between the groups. The group which was run under the differential stimulation provided by relevant drives learned much more quickly.

The results are interpreted as providing evidence that the differential proprioceptive stimulation arising from differential fractional anticipatory goal responses play an important role in selective learning. This is thought to be due in part to the fact that such stimulation has its onset immediately preceding the particular response to which it becomes conditioned.

(Manuscript received January 6, 1949)

References

1. Amsel, A. An experimental study of drive combination. In press, *J. exp. Psychol.*
2. Farber, I. F. Response fixation under anxiety and non-anxiety conditions. *J. exp. Psychol.*, 1948, **38**, 111–131.
3. Grant, D. A. New statistical criteria for learning and problem solution in experiments involving repeated trials. *Psychol. Hull.*, 1946, **43**, 272–281.
4. Hull, C. L. Knowledge and purpose as habit mechanisms. *Psychol. Rev.*, 1930, **37**, 511–525.
5. Hull, C. L. Goal attraction and directing ideas conceived as habit phenomena. *Psychol. Rev.*, 1931, **38**, 487–506.
6. Hull, C. L. Goal gradient hypothesis and maze learning. *Psychol. Rev.*, 1932, **39**, 25–43.
7. Hull, C. L. Differential habituation to internal stimuli in the albino rat. *J. comp. Psychol.*, 1933, **16**, 255–273.
8. Hull, C. L. *Principles of behavior.* New York: D. Appleton Century, 1943.
9. Kappauf, W. E., & Schlosberg, H. Conditioned responses in the white rat. III. Conditioning as a function of the length of the period of delay. *J. genet. Psychol.*, 1937, **50**, 27–45.
10. Kendler, H. H. The influence of simultaneous hunger and thirst drives upon the learning of two opposed spatial responses

of the white rat. *J. exp. Psychol.*, 1946, **36**, 212–220.

11. LEEPER, R. The role of motivation in learning: A study of the phenomenon of differential motivational control of the utilization of habits. *J. genet. Psychol.*, 1935, **46**, 3–40.
12. SPENCE, K. W. Symposium: learning as related to need, and the subsequent motivation of such learned behavior. *Psychol. Bull.*, 1941, **38**, 721.
13. SPENCE, K. W. Theories of learning. In: Chapt. IV in STEVENS, S. S. (ed.), *Handbook in experimental psychology*. Wiley and Co. (To be published.)
14. WEBB, W. B. An experimental study of the role of an irrelevant drive in the behavior of the white rat. Ph.D. Thesis, State University of Iowa, August, 1947.

SPATIAL LEARNING IN THE T-MAZE: THE INFLUENCE OF DIRECTION, TURN, AND FOOD LOCATION

BY HUGH C. BLODGETT, KENNETH McCUTCHAN, AND RAVENNA MATHEWS

University of Texas[1]

This article is concerned with a study of the manner in which certain spatial relations are involved in the learning of an elevated simple T-maze. The relationships singled out for study are: (1) position of the food box with reference to other loci in the experimental room; (2) directional axis from the choice point to the food box; and (3) response (i.e., right turn or left turn) leading from the choice point toward the food box.

These are aspects of the situation which may have an important influence on the development of spatial learning. Tolman, Ritchie, and Kalish (10), for example, have assumed that after several trials on a maze the rat develops a 'cognitive map' of the environment, and along with it the ability to go to the location in the room where food has been experienced. This kind of learning they have called 'place' learning, and the disposition to go to the food, a 'place disposition.'

In the second article of the series, "Studies in Spatial Learning," these investigators (11) trained a group of rats on two alternate arrangements of a simple T-maze shown in Fig. 1. The rats always found food, let us say, at location F_1, but in half of the trials they started at S_1 and made a left turn at C, while in the remaining trials they started at S_2 and made a right turn at C. Tolman, Ritchie and Kalish believe the learning shown by this group to be an example of pure 'place' learning.

[1] The expense involved in this study was, in part, met by a grant from the Graduate Research Council of the University of Texas.

If they are correct in this belief, it is still uncertain just what the learning comprised. In both of the maze arrangements, the position of the food box was identical. Likewise, the direction, within the room, from the choice point to the food location was always the same. It appears, therefore, that the rats may have acquired either a disposition to go to the location in the room where food had been experienced, as Tolman, Ritchie, and Kalish thought, or a disposition to go in a direction parallel to that of the

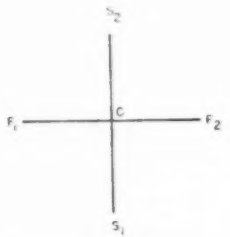


FIG. 1. Schematic reproduction of maze used by Tolman, Ritchie, and Kalish (10)

maze axis from the choice point toward the food location. It should be pointed out, moreover, that these two dispositions may lead to different, even to opposed, spatial behavior. Consider, for example, the case in which rats have learned the T-maze shown schematically in Fig. 2. Prior to training on this maze, we shall say, these rats have become familiar with the spatial aspects of the room—have had a chance to develop a 'cognitive map' of the room environment. Let us now assume that during training on the T-maze they have acquired a

FIG. 2. Schematic design for differential test of direction disposition and place disposition

disposition to go in a direction parallel to the axis of the maze from choice point to food box. If, subsequently, we place them on the maze S_2-C_2 shown in dotted lines in Fig. 2, we should expect them, as a result of generalization of the direction disposition, to go along a projection of the vector C_1-F_1 toward F_2—actually away from the food location. Contrariwise, to the extent that their behavior is determined by a place disposition, we should expect them to go from C_2 to the food location at F_1. In the experiment by Tolman, Ritchie, and Kalish no distinction was made between these two possible dispositions. The experiment was not calculated to differentiate between them.

In an attempt to make such a differentiation we studied the influence, first singly and then jointly, of the three spatial relationships mentioned at the beginning of this paper. Groups of rats were trained on a simple T elevated maze set interchangeable at two positions in the laboratory room. For certain groups only one spatial aspect, either the position of the food box, the direction from choice point to food box, or the turn (i.e., left or right) at the choice point, was common to the two placements. For other groups two of the three aspects were common to the placements. A final group placed always at the same position combined all three aspects.

The comparative rate of learning shown by groups experiencing different common spatial relationships gave us an indication of the functional influence of these relationships.

ANIMALS

Subjects were 104 white rats, approximately 60 days old, with no prior maze experience. The rats, which were reared in the colony maintained by the psychology department at The University of Texas, were fed Purina Chow pellets and had access to water in their home cages. They were housed in the colony room and were not taken into the experimental room before the beginning of the experiment.

APPARATUS AND EXPERIMENTAL SETTING

The maze shown in Fig. 3 was used in the training of all groups. It was assembled from a stock of elevated units which were interchanged at each trial. The units were constructed of dressed pine painted flat black. Dimensions were $3\frac{1}{2} \times 24$ in. with track 15 in. above the floor. Food boxes stood at the end of both arms of the T, but food was available only in the correct box. At any trial only one maze stood in the room, though all groups, except one, ran the maze at two distinct placements.

Dimensions and features of the experimental room are shown in Fig. 3. Windows were un-

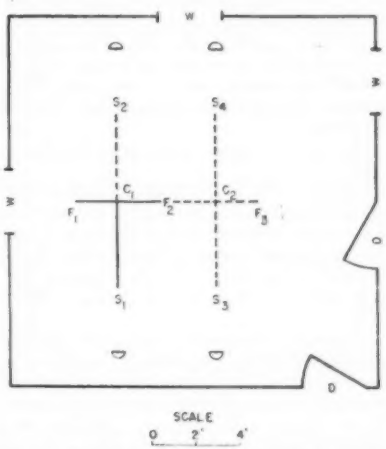


FIG. 3. Plan of experimental room showing maze placements used in Experiment I

shaded and no artificial lighting was used. Walls and ceiling were neutral plaster, and the floor was painted dull grey. The only object in the room besides the maze and food boxes was a chair. The experimenter stood approximately three feet from the base of the T in line with the stem.

PROCEDURE

For five days preceding the experiment animals were given preliminary training on a five-foot straight elevated path and fed for about three minutes in the food box. Both track and food box were the same in construction as those used in the training experiment. Preliminary training was not given in the experimental room.

The experiment was conducted daily from approximately 2:30 P.M. until 4:00 P.M. After each trial rats were given .5 gm. of Purina meal moistened with water. Following the last trial each day they were returned to their home cage and given supplementary Purina Chow pellets. Trials followed approximately 23.5 hours of food deprivation. Throughout the experiment the rats were given sufficient food to maintain a steady rate of growth.

Experiment 1

Method.—Training consisted of four trials a day for 12 days. Rats were brought into the experimental room one at a time, given a trial and then removed to the colony room while other members of the group were run. This routine was repeated until each rat had received four trials. The interval between trials was about five min.

Scoring.—Body-length entry into the incorrect arm of the T was scored as an error. Error scores were kept in cycles, each cycle consisting of a trial on one placement and a sequential trial on the second placement. If a rat made an error on either or both trials, the cycle was scored as incorrect.

Fig. 3 gives maze placements for Experiment 1.

Group I: Place; Eight rats.—For this group the food location was common to the two maze placements, S_1-F_2 and S_3-F_2. Turns at C_1 and C_2 were opposed, and direction from C_1 to F_2 was opposed to that from C_2 to F_2. Starting positions were S_1 S_3 S_2 S_1 and on alternate days S_3 S_1 S_1 S_3.

Group II: Direction; Eight rats.—For this group direction from choice point to food location was common to the two maze placements. The two locations were distinct and turns at the choice points were opposed. Subjects were trained against the direction chosen on the initial trial. Five rats were trained at placements S_1-F_1 and S_4-F_2; three at S_1-F_2 and S_4-F_3. Start positions were S_1 S_4 S_4 S_1 and on alternate days S_4 S_1 S_1 S_4.

Group III: Response; Eight rats.—The turn at the choice point was common to the two placements. The two food locations F_1 and F_2 were distinct and direction from C_1 to F_1 was opposed to that from C_1 to F_3. Subjects were trained against the turn made on the initial trial. Five rats were trained at maze placements S_1-F_1 and S_2-F_2; three at S_1-F_2 and S_2-F_1. Start positions were S_1 S_2 S_2 S_1 and on alternate days S_2 S_1 S_1 S_2.

Group IV: Place plus Direction; Eight rats.—Direction and food location were common to the two maze placements but turns were opposed. Subjects were trained against the direction and the position chosen on the initial trial. Four rats were trained at maze placements S_1-F_1 and S_2-F_1; four at S_1-F_2 and S_2-F_2. Start positions were S_1 S_2 S_2 S_1 and on alternate days S_2 S_1 S_1 S_2.

Group V: Place plus Response; Eight rats.—Food location and turns at the choice points were common to the two maze placements, but direction from C_1 to F_2 were opposed to that from C_2 to F_2. All rats were trained at placements S_1-F_2 and S_4-F_2. Start positions were S_1 $S_4$$S_4$ S_1 and on alternate days S_4 S_1 S_1 S_4.

Group VI: Direction plus Response; Eight rats.—Direction from choice point to food location and turns at the choice points were common to the two maze placements. Food locations were distinct. Subjects were trained against the direction and the turn made on the initial trial. Five rats were trained at placements S_1-F_1 and S_2-F_2; three at placements S_1-F_2 and S_2-F_3. Start positions were S_1 S_2 S_2 S_1 and on alternate days S_2 S_1 S_1 S_2.

Group VII: Direction plus Place plus Response; Eight rats.—All trials were at a fixed maze placement, with the start position always at S_1. Subjects were trained against the response made on the initial trial. Four rats were trained at placement S_1-F_1; four at placement S_1-F_2.

Experiment 2

Method.—Training consisted of two trials a day for 10 days. In all other respects training procedure was like that in Experiment 1.

Scoring.—The scoring procedure was the same in both experiments.

For the Direction plus Place Group, as in Experiment 1, the choice point in both placements was at the same position. For the Direction Group choice points were 26 in. apart. (In Experiment 1 they were 54 in. apart.) Two response groups were used. One of these, Group X, had a fixed choice point. The other, Group XI, had choice points 26 in. apart.

Fig. 4 gives the maze placements for Experiment 2.

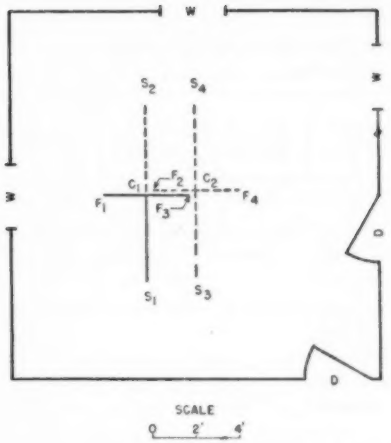


FIG. 4. Plan of experimental room showing maze placements used in Experiment 2

Group VIII: Response; Eleven rats.—The turn at the choice point was common to the two maze placements, but the food locations were distinct and the direction from C_1 to F_1 was opposed to that from C_1 to F_3. Group VIII differed from Group III of Experiment 1 only in the position of C_1, which was 14 inches east of the placement used for the latter group. Subjects were trained against the turn made on the initial trial. Four rats were trained at placements S_1-F_1 and S_2-F_3; seven at S_1-F_3 and S_2-F_1. Start positions were S_1 S_2 and on alternate days S_2 S_1.

Group IX: Response; Eleven rats.—Group IX differed from Group VIII only in that choice points were 26 in. apart along the lateral axis of the maze. Subjects were trained against the turn made on the initial trial. Four rats were trained at placements S_1-F_1 and S_4-F_4; seven at S_1-F_3 and S_4-F_2. Start positions were S_1 S_4 and on alternate days S_4 S_1.

Group X: Direction plus Place; Thirteen rats.—For Group X, as for Group IV of Experiment 1, direction and food location were common to the two maze placements, but turns were opposed. Group X differed from Group IV in the location of C_1. Subjects were trained against the direction chosen on the initial trial. Six rats were trained at maze placements S_1-F_1 and S_2-F_4; seven at S_1-F_3 and S_2-F_2. Start positions were S_1 S_2 and on alternate days S_2 S_1.

Group XI: Direction; Thirteen rats.—For Group XI, as for Group II of Experiment 1, direction was common to the two maze placements. Subjects were trained against the direction chosen on the initial trial. Five rats were trained on maze placements S_1-F_1 and S_4-F_2; eight on S_1-F_3 and S_4-F_4. Start positions were S_1 S_4 and on alternate days S_4 S_1.

RESULTS

Experiment 1

The average number of incorrect cycles for each group is given in Table I. Group differences are also shown.

The groups that made fewest incorrect cycles are those in which direction was common to the two maze placements. Group II, which had only direction as the common aspect, made fewer incorrect cycles than Group V, which had both food location and turn common to the two placements.

The score of the Response Group fell between those of the Direction Group and the Place Group. The Place Group had an error score significantly larger than that of any of the other six groups. Although few of the differences are statistically significant, the systematic order of group means is striking. One notices that combining food location with either of the other two spatial aspects does not greatly change the score associated with those aspects. The score of the Place plus Direction Group differs little from that of the Direction Group. Likewise the score of the Place plus Response Group differs little from that of the Response Group, but both the Direction Group and the Response Group have significantly lower error scores than the Place Group.

Experiment 2

Table II gives the average number of incorrect cycles for each group and the differences between averages. As in Experiment 1, groups having common direction in the two placements made fewer incorrect cycles than

TABLE I

AVERAGE NUMBER OF INCORRECT CYCLES PER GROUP AND GROUP DIFFERENCES *
(Experiment 1. Cycles 2–24)

	Group VI Direction plus Response Av. = 7.1	Group IV Place plus Direction Av. = 7.2	Group II Direction Av. = 9.7	Group V Place plus Response Av. = 10.5	Group III Response Av. = 11.9	Group I Place Av. = 17.4
Group VII Place plus Response plus Direction Av. = 4.7	Diff. = 2.4 t = 1.54	Diff. = 2.5 t = 1.90	Diff. = 5.0 t^1 = 2.50	Diff. = 5.8 t^1 = 2.39	Diff. = 6.2 t^2 = 2.70	Diff. = 12.7 t^2 = 6.05
Group VI Direction plus Response Av. = 7.1		Diff. = 0.1 t = 0.04	Diff. = 2.6 t = 1.16	Diff. = 3.4 t = 1.33	Diff. = 4.8 t = 1.92	Diff. = 10.3 t^2 = 4.38
Group IV Place plus Direction Av. = 7.2			Diff. = 2.5 t = 1.28	Diff. = 3.33 t = 1.39	Diff. = 4.7 t = 2.09	Diff. = 10.2 t^2 = 4.90
Group II Direction Av. = 9.7				Diff. = 0.8 t = 0.31	Diff. = 2.2 t = 0.91	Diff. = 7.7 t^2 = 3.39
Group V Place plus Response Av. = 10.5					Diff. = 1.4 t = 0.50	Diff. = 6.9 t^2 = 2.82
Group III Response Av. = 11.9						Diff. = 5.5 t^1 = 2.20

* df = 14; t^1 = significant at the 5 percent level of confidence; t^2 = significant at the 2 percent level of confidence; t^3 = significant at the 1 percent level of confidence.

either of the two response groups. The Direction Group made a lower error score than did the Direction plus Place Group. This emphasizes the relatively slight influence of food location in our experimental setting.

TABLE II

AVERAGE NUMBER OF INCORRECT CYCLES PER GROUP AND GROUP DIFFERENCES
(Experiment 2. Cycles 2–10)

	Group X Direction; Choice-Points Constant Av. = 5.2	Group IX Response; Choice-Points 26 in. Apart Av. = 6.8	Group VIII Response; Choice-Points Constant Av. = 7.6
Group XI Direction Choice-Points 26 in. Apart Av. = 3.7	Diff. = 1.5 t = 1.24 df = 24	Diff. = 3.1 t = 2.05 df = 22	Diff. = 3.9 t^1 = 2.53 df = 22
Group X Direction plus Place Choice-Points Constant Av. = 5.2		Diff. = 1.6 t = 0.94 df = 22	Diff. = 2.4 t = 1.39 df = 22
Group IX Response Choice-Points 26 in. Apart Av. = 6.8			Diff. = 0.8 t = 0.39 df = 24

t^1 = significant at 2 percent level of confidence.

Conclusions and Discussion

We have shown that, when a simple T-maze is learned at two interchangeable placements, common direction from choice point to food location results in a facilitation of learning not otherwise found. This suggests that at each placement a direction disposition is acquired, and, in our various experimental situations, generalizes freely to the other placement, thus bringing about mutual facilitation.

When direction from two distinct choice points to a common food location is opposed mutual interference develops between learning at the two placements. This is shown strikingly in the Place plus Response Group of Experiment 1. Only three members made as many as four consecutive correct cycles during the 24-cycle period.

The influence of common direction is not restricted to those placements in which the choice points stand at the same locus. In Experiment 1, the choice points for the Direction Group were 54 in. apart, whereas for the Place plus Direction Group the choice points stood at the same position. Yet the scores of these groups did not differ from one another significantly. Likewise, in Experiment 2 the choice points for the Direction Group were 26 in. apart while those for the Direction plus Place Group were always at the same position. Scores were not significantly different. Thus, generalization of the direction disposition is effective, and about equally so, whether the choice points are at an identical position, 26 in. apart or 54 in. apart.

The evidence presented indicates that a common response (i.e., turn) at the choice points results in some facilitation not found when response is opposed. Error scores of the Direction plus Response Group, for example, were somewhat lower, though not significantly so, than the scores for the Direction Group. More important, scores of the Response plus Place Group were significantly lower than those of the Place Group. For the Place Group, the combination of interference brought about by opposed direction dispositions and opposed response dispositions resulted in pronounced retardation of learning. Of the eight subjects in this group only one made as many as four consecutive perfect cycles during the 24-cycle training period.

In Experiment 2 the scores of the two response groups are of special interest. For Group VIII the common turn occurred at the same position, C_1, in both placements; where as for Group IX it occurred at C_1 and C_2, 26 in. apart. The error scores of the two groups, however, were not significantly different. Thus generalization of the response dispositions is as great from choice points 26 in. apart as at a fixed position. This may be regarded as disagreeing with Ritchie's (8) assumption that "in situations where there are marked extra maze cues, turn dispositions (e.g., to the right) do not generalize to new starting positions."

We find no evidence that our subjects have acquired a place disposition. Concurrent training on different paths leading to the same food location resulted in no apparent mutual facilitation. We believe, therefore, that the 'place' learning observed by Tolman, Ritchie, and Kalish (11) consisted chiefly of a direction disposition parallel to the final maze vector C-F.

There is apparent agreement between our findings and those observed in other experiments on spatial learning. Ritchie (8) has obtained evidence supporting

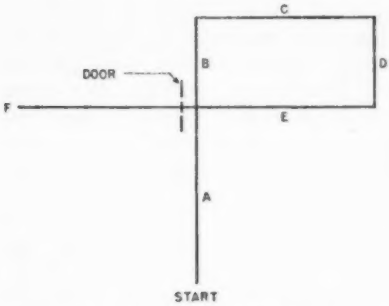


FIG. 5. Schematic drawing of Shepard's "circuit" maze

the view that rats acquire a direction disposition in learning a simple T-maze. He found no evidence that they acquire a place disposition. Wilcoxon and Waters (13) and Brown, Gentry, and Kaplan (3) also failed to obtain evidence that would indicate the acquisition of a place disposition.

Two of the present writers, Blodgett and McCutchan (1), in a series of experiments found that if the critical choice point in the double-pattern maze was one in which, at one trial, a given response was appropriate, and at a later trial, a spatially opposed response was appropriate, learning was greatly retarded. This finding was subsequently confirmed by Kalish (6) for one of the experimental situations employed by Blodgett and McCutchan. In the experiments just cited, however, the nature of interference at the choice point was not determined. It might have derived from opposition either between turns or between direction at the critical choice point. We are now ready to conclude that the effect of spatial opposition observed in our earlier experiments derived, at once, from interference between opposed response dispositions and from interference between opposed direction dispositions. Of these two, interference between direction dispositions was probably the stronger.

It is possible that interference between direction dispositions may, in part, account for a number of puzzling results reported by various investigators. One example (5) is the difficulty of the temporal maze. It seems likely that this derives from opposition between direction dispositions associated with the critical choice point.

FIG. 6. Schematic drawing of semilinear maze

Another example is a finding reported by Shepard (9) (Fig. 5). He trained rats to run along a straight alley A, past a closed door set in a second alley F which led to a food box. After passing the door, the rats ran the circuit B-C-D-E, doubling across A into alley F. The door at the entry to alley F was now open. Shepard found to his surprise that after the first few trials, rats would not run past alley F and around the circuit. Instead they stopped at the junction of A and F as if waiting for the door to open. Maier (7) observes that the rats may have keen enough sensory discrimination to recognize the junction and the blind character of the circuit. This he thinks would cause them to wait at the junction until the door into alley F was opened. Our explanation would be that during the first few trials the rats acquire a direction disposition parallel to the axis of alley F from the junction toward the food location. This conflicts with and tends to inhibit the evocation of any other directional response at the junction point.

Another puzzling finding is that in the linear maze of pattern type LRLRLR-LRLRLL, Fig. 6, most rats anticipate the turn C-F at point X and make the congruent (but incorrect) response X-Y. It appears to us that this anticipatory response may be a generalized response in which a direction disposition parallel to C-F transposes to position X. It is unlikely that the rat can discriminate between loci C and X; therefore, the direction disposition supported upon locus C is evoked at X, its stimulus equivalent.

A problem which has not as yet been raised relates to the number of direction dispositions involved in spatial learning. Ritchie and the present writers have concerned themselves with one direction disposition only—that coinciding with the direction of the final alley of the maze from choice point toward food box. It seems likely, however, that other direction dispositions are acquired, one being associated with each discriminable axis of the maze.

This view appears to gain support from two recent experiments. Two of the present writers, Blodgett and McCutchan, have obtained results to be published later which tend to show that a direction disposition may be associated with a sub-goal in the linear maze. The directional axis at the sub-goal was one that differed by 180° from that of the maze path leading from the final choice point toward the food box. Supporting evidence also comes from an experiment by Gentry, Brown, and Lee (4). These investigators first trained rats to run from a start position to a circular platform and from this over an eight-alley elevated multiple T-maze. At the end of the training period the maze was removed and in its place ten radial paths were set up around the circular platform. Rats introduced onto the platform showed a significant tendency to choose the two paths most nearly coinciding with the directional axis of the maze at that location in the room where the rats' forward progress had been blocked. They showed no tendency to go from the blocked path directly to the location of the food box. This finding indicates that, in the multiple T-maze, the rat may learn other direction dispositions than the one associated with the final goalward path.

We do not believe that direction dispositions are to be identified with the 'psychological component' of maze behavior which Tryon (12) has designated as 'direction set,' or with the one which he has related to entry into 'food-pointing' culs. Tryon, after an examination of the records of a large number of rats made on the Tryon X maze, decided that the behavior of his subjects could be resolved into a relatively few components. Among these were several which he called 'direction sets,' derived from "certain abstract lines of direction inherent in the maze design." These sets affected the behavior of the rats 'even on the first trial.' One finds, upon examination of Tryon's diagrams, that his 'direction sets' have no relationship to the direction disposition considered in Ritchie's paper (8) or in the present article.

Of the 'food-pointing' component

Tryon says, "The piling up of errors in food-pointing blinds suggests that the rats readily take a food orientation which also has an abstract character as there are no specific cues to elicit it." Only one of the blinds designated by Tryon as 'food-pointing' is parallel to the axis of the maze from final turn to food box. The others point toward the final path but run at right angles to it. Entry into these alleys does not therefore indicate a direction disposition coinciding with the axis from choice point toward food box.

We shall refer to one more of the psychological components listed by Tryon. This one, which he designates as 'short-cut,' was observed at five culs, 1, 3, 7, 15 and 17, in his maze. At these positions rats gave the appearance of trying to shunt out a later maze section. The phenomenon of the apparent short-cut has been observed before and frequently commented upon. It is one of the bases for the belief in 'cognitive mapping' in the rat. This behavior may possibly result from generalization of a direction disposition. It will be seen that in all of the culs in which Tryon's rats attempted the short-cut, the axis of the cul is parallel to that of a later section of the maze path and in all cases it is near the later alley. Blinds 1 and 17 are coterminous with the exit path. Blind 15 abuts on the exit. Blind 3 lies near and parallel to alley 7. Blind 7 lies parallel to alley 15. Place discrimination between these blinds and the nearby alleys would hardly be possible. Now, if the rats acquire direction dispositions at various segments of the maze, one could predict the very behavior observed by Tryon. Parts of the maze lying close together would not be discriminated, and, where axes of the segments were opposed, conflict would develop between direction dispositions associated with those segments. Because of the influence of the goal gradient, the stronger of two direction dispositions would be the one associated with that maze segment lying nearer the goal. This, in Tryon's X maze, would result in an increased number of errors in the so-called 'short-cut' blinds. We think that direction dispositions are probably involved in many of the cases of short-cut, insight, reasoning, and cognitive-map behavior described in the literature.

Summary

We undertook to differentiate between the effects, in learning an elevated T-maze, of three spatial aspects of the learning situation. These were: (1) position of the food box with reference to other loci in the experimental room, (2) directional axis from the choice point to the food box, and (3) turn (i.e., left or right) from choice point to food box.

Our procedure was to train groups of white rats on a T-maze placed interchangeably at two positions within the experimental room. For certain groups only one of the three spatial aspects was common to the two placements. For other groups two of the aspects were common, and for one group, all three aspects were constant. Comparison of the rate of learning shown by the different groups gave us an indication of the effect of the relationships.

The group having direction as a common spatial aspect made the lowest error scores. This indicates that mutual facilitation occurred at the maze placements as a result of this common aspect, and suggests that at each maze position a direction disposition was acquired and generalized to the other position.

When direction from choice point to food box was opposed in the two maze placements, mutual interference occurred and impeded learning of other types of disposition.

The groups having a common turn at the two placements made lower error scores than groups having only food box location as the common aspect. This indicates that mutual

facilitation occurred as a result of the common turn, and suggests that a response disposition was acquired at each maze position and generalized to the other position.

When the turn at the two maze placements was opposed, mutual interference occurred and impeded learning of other types of disposition. Interference deriving from opposed turn was less than that from opposed direction.

We conclude that in learning the elevated simple T-maze the rat acquires a direction disposition and of lesser strength a response disposition. We obtained no evidence that the rats acquired a place disposition.

We have considered the bearing of our findings upon several other investigations of maze learning.

(Manuscript received January 25, 1949)

References

1. Blodgett, H. C., & McCutchan, K. Choice point behavior in the white rat as influenced by spatial opposition and by preceding maze sequence. *J. comp. Psychol.*, 1944, **37**, 51–70.
2. Blodgett, H. C., & McCutchan, K. Place learning and anticipation. I. Anticipation as failure of place discrimination. *J. comp. Psychol.*, 1946, **39**, 351–357.
3. Gentry, G., Brown, W. L., & Kaplan, S. J. An experimental analysis of the spatial location hypothesis in learning. *J. comp. physiol. Psychol.*, 1947, **40**, 309–322.
4. Gentry, G., Brown, W. L., & Lee, H. Spatial location in the learning of a multiple-T maze. *J. comp. physiol. Psychol.*, 1948, **41**, 312–318.
5. Hunter, W. S. The temporal maze and kinaesthetic sensory processes in the white rat. *Psychobiol.*, 1920, **2**, 1–18.
6. Kalish, D. The non-correction method and the delayed response problem of Blodgett and McCutchan. *J. comp. Psychol.*, 1946, **39**, 91–108.
7. Maier, N. R. F., & Schnierla, T. C. *Principles of animal psychology*. N. Y.: McGraw-Hill, 1935.
8. Ritchie, B. F. Studies in spatial learning. VI. Place orientation and direction orientation. *J. exp. Psychol.*, 1948, **38**, 659–669.
9. Shepard, J. F. More learning. *Psychol. Bull.*, 1931, **28**, 240–241.
10. Tolman, E. C., Ritchie, B. F., & Kalish, D. Studies in spatial learning. I. Orientation and the short-cut. *J. exp. Psychol.*, 1946, **36**, 13–24.
11. Tolman, E. C., Ritchie, B. F., & Kalish, D. Studies in spatial learning. II. Place learning versus response learning. *J. exp. Psychol.*, 1946, **37**, 221–229.
12. Tryon, R. C. Studies in individual maze ability. VII. The specific components of maze ability, and a general theory of psychological components. *J. comp. Psychol.*, 1940, **30**, 283–335.
13. Wilcoxon, H. C., & Waters, R. H. Spatial orientation in the white rat. *J. exp. Psychol.*, 1948, **38**, 412–419.

STUDIES IN LEARNING AND MOTIVATION: I. EQUAL REINFORCEMENTS IN BOTH END-BOXES, FOLLOWED BY SHOCK IN ONE END-BOX

BY EDWARD C. TOLMAN AND HENRY GLEITMAN

University of California

Introduction

A number of studies have been published during the last several years designed to test certain aspects of the sign-Gestalt theory of learning—in particular the phenomenon of 'latent learning.'[1] Based for the most part on an experimental test proposed some time ago by White (16), these recent studies have used a rather simple experimental situation. A rat is placed in a one-choice T-maze or Y-maze containing food at one end and water at the other. If the animal is run thirsty until he has learned to turn towards the side containing water—adequate measures being taken to insure objectively equal experience with both sides—, what will be his response later when he is satiated for water but deprived of *food* and again run in the maze? The experimental answer to this question was first provided by Spence and Lippitt (10), who found that, in correspondence with the predictions of Hull's (3) reinforcement theory, all their animals continued to run to the side on which they had been originally rewarded.[2] These authors interpreted their results as indicating that the animals had not learned the location of the food during their original training period. For the most part this conclusion seems to have been confirmed by later investigators. Walker (14) and Kendler (4) obtained similar results using somewhat different maze set-ups from one another and from the original Spence and Lippitt maze, and Kendler and Mencher (5) showed that such results could not be ascribed to a mere lack of perceptual acquaintance with the food as Leeper (6) had suggested. On the whole, then, it seems probable that rats do not readily learn the location of one type of goal-object when under another different drive. We must conclude that at least in such situations it is relatively difficult to obtain evidence of latent learning.[3]

The failure of such experimental situations to demonstrate latent learn-

[1] The concept of latent learning was originated by Blodgett (1) and he presented the first experimental evidence for it. His findings were subsequently confirmed by others, for example, Tolman and Honzik (12). And the senior author (11) relied upon these early findings *re* latent learning as basic support for his sign-Gestalt, or expectancy, theory of learning.

[2] It is to be emphasized that these results actually correspond with Hull's theory only if it be assumed that the specific S_D for thirst did not become an important item in the original habit formed. Otherwise, the change from the thirst S_D to the hunger S_D should have caused some breakdown in the tendency to take the water side. Spence and Lippitt get around this by speaking of a 'generalized drive' resulting from thirst and being the same when the hunger was subsequently introduced.

[3] A further experiment by Walker (15), as yet unpublished, reported at the A.P.A. meetings, September 1948, did, however, demonstrate latent learning in a similar set-up. Hungry rats did learn the location of food when run thirsty to water, so that when later made hungry they chose the food side. In his set-up there were no forced trials. Water was on both sides. But in getting to the water in the preliminary training they went through a food compartment on one side and did not on the other. And then when made hungry they chose the side where the food compartment was. (Private communication from Walker.)

ing has been considered by some writers as an argument against the possibility of latent learning under any conditions and therefore as a severe blow to the sign-Gestalt theory of learning. However, while it is true that a prediction made by sign-Gestalt theorists has been tested and found erroneous, this does not necessarily invalidate the basic concepts underlying the theory. For the sign-Gestalt theory does not necessitate the assertion that latent learning will occur in every instance, but insists merely that reinforcement is not a necessary condition of *all* learning. On the other hand, the reinforcement theorist is forced by the very nature of his doctrine to deny the possibility of latent learning in any instance whatever.

It was the purpose of the present investigation to find an experimental situation relatively similar to the Spence and Lippitt set-up that would demonstrate latent learning, and to attempt to determine some of the factors which might contribute to its presence or absence in such situations.

Let us consider the different interpretations suggested for a rat's mastery of a T-maze. According to the reinforcement theory what is learned is a sequence of responses leading to reinforcement. In terms of the choice situation, what is learned is the correct turning response as opposed to the wrong one. The correct one leads to a reinforcing state of affairs, the wrong one does not, and accordingly the stimulus complex presented at the choice point acquires a greater tendency to evoke the reinforced turn. Presumably no differentiation between the responses could be obtained if either response were equally rewarded or reward withheld from both —nothing should be learned in such a situation. On the other hand, the sign-Gestalt theory holds that the rat learns not only the correct turn, but also other perceptual relationships within the maze, regardless of their reward value; he forms what the senior author has recently called a 'cognitive map' (13). In other words, the animal acts as if he has some 'notion' as to what each side contains —this 'notion' being demonstrated (either during the training situation as in the orthodox maze learning curve or in later performance as in the latent learning experiments) by the appropriate turn at the choice point. It is clear that our knowledge is as yet inadequate to predict the precise nature of rats' 'notions'—i.e., which perceptual differences will be learned in this manner, under what motivational states, and the like. However, the sign-Gestalt theory can at least make the very general statement that *some* perceptual relationships will tend to be learned.

Perhaps one can then restate the latent learning hypothesis in its most general form: Under *certain* conditions, *some* discriminanda or the *relationships between some discriminanda* will be learned by the organism even though these discriminanda bear no differential relationship to reinforcement. This is admittedly a very general and a very cautious statement of the hypothesis. However, it is considered fruitful in so much as it offers a framework for further investigation of the particular conditions surrounding its application. And despite this statement's generality, reinforcement theory would nonetheless be forced to deny it.

Purpose and General Plan of Experiment

I. The primary purpose of the present experiment was to find a

situation within which the discriminanda differences are such as to be learned by rats, even though these differences are not related to reinforcement.

The plan of experiment was modelled somewhat after the Maier reasoning experiments (7), involving the integration of two experiences:

A. Situation 1: The animals were run in a maze containing two highly differentiated end-boxes. This differentiation, however, was not related to reinforcement.

B. Situation 2: Subsequent to Situation 1, the animals were placed in one of the end-boxes and were given an electric shock, while finding food in the other end-box. This Situation was presented in another room.

C. Test situation: Subsequent to Situation 2, the animals were again placed into the maze, and their choice rewarded.

II. An additional attempt was made to determine whether differences in strength of motivation in the original learning would have any bearing on the later avoidance in the test situation of the side leading to the end-box in which the animals had experienced the shock.[4]

Apparatus

The design of the apparatus to be used for this experiment posed a certain problem. It was necessary to design a maze the end-boxes of which were as perceptually differentiated as possible, yet to be sure at the same time that these differences were not perceptible from the choice point. Failure to control this latter factor adequately would render any results inconclusive, inasmuch as positive results might then be due either to true latent learning under Situation 1, or merely to the recent experience under Situation 2. The latter results could easily be explained on a reinforcement basis—as a response away from a stimulus at the choice point that had been contiguous with punishment in Situation 2. On the other hand, if a difference be not apparent from the choice point, then a positive reaction (i.e., the animal running away from the side containing the end-box he was shocked in) can only be attributed to learning under Situation 1, a possibility denied by reinforcement theory.[5]

The apparatus used consisted of a simple alley maze, as shown in Fig. 1. The two end-sections A and B contained the two end-boxes and a 22-in. runway to each. Both of the end-sections could be detached from the maze in their entirety. A small box was set into the far wall of each of the two end-boxes to serve as a food container. The floor of both end-boxes was fitted with a wire grill, to allow shocking the animals during the second part of the experiment.

One-way doors made of aluminum were hinged at points R, S, T, U, V, W, X, and Y to prevent retracing. Doors T and U could be locked by the experimenter when necessary to

[4] An as yet unpublished experiment of this same design was earlier carried out in the California laboratory by R. J. Schweers. The results he obtained were similar to those we shall report. Schweers, therefore, deserves credit for suggesting our experiment.

An abstract of an experiment of a somewhat similar nature by Seward (9) has also appeared. His animals were first allowed to explore a T-maze having two different end-boxes and then rewarded in one of them. The animals were then started from the entrance to the maze and a large majority then ran to the side on which they had been fed. In short, he also obtained latent learning.

[5] It is to be pointed out that the design of our experiment is closely related to that of an earlier experiment by Honzik and Tolman (2). In the Honzik and Tolman experiment hungry rats also ran a T-maze obtaining food at either end of the arms of the T. In this experiment, however, one of the arms of the T was shorter than the other, so that the animals developed a strongly preferred side. The animals were then shocked in the end-box on this preferred side—with this end-box, however, *in situ* and not as in the present experiment in another room. When then started again on the leg of the T a large proportion of the animals ran to the other, or non-shocked, side. However, it appeared from a series of control experiments also carried out that these results were dependent upon general visual cues. And, since there was directional lighting in the room, it appears to the present writers that such results may well have been due to some common features between the visual cues at the end-box where the animals were shocked and those on the path which led to this end-box. Hence the present prescriptions were not fully fulfilled by the Honzik and Tolman experiment.

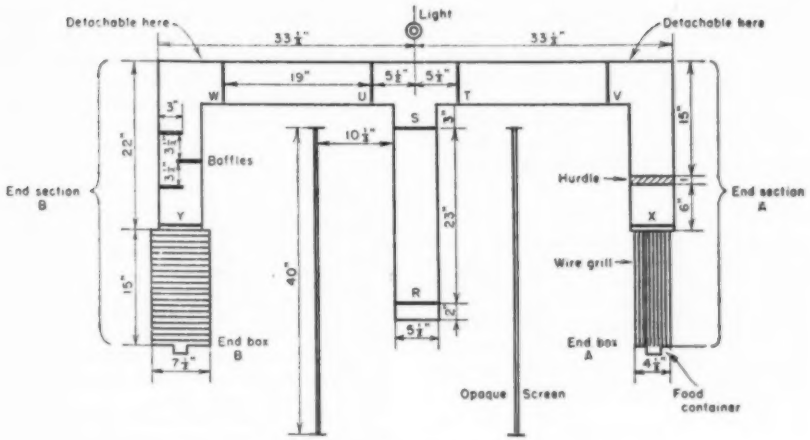


FIG. 1. Floorplan of maze

R, S, T, U, V, W, X and Y are one-day doors. Some other dimensions of the apparatus not indicated on the diagram are as follows:

The maze walls were 6 in. high. The hurdle in End-section A was 2½ in. high. The wires in each grill in the end-boxes were separated by ½ in., there being nine wires in End-box A, 20 in End-box B. All the one-way doors were hinged at a point 5½ in. from the floor, excepting only one-way door X, which was smaller and was hinged at a point 3½ in. from the floor.

permit forced trials to the opposite side. Doors X and Y were painted black, all others were white.

An effort was made to create the greatest possible perceptual differences between the two end-sections. End-section A was painted black and was totally unilluminated except for whatever stray light might enter through the small food container opening. The end-box in section A was narrower than that in section B and the grill was fitted in parallel lines to the end-runway. Furthermore, a little hurdle, about 2½ in. high and ½ in. thick, was placed in the middle of the runway, and the one-way door X, leading from the end-runway to the end-box, was smaller and hinged lower than the corresponding one for end-box B.

In contrast end-section B was left unpainted, and the end-box of the section was strongly illuminated by a 60 watt bulb set into a housing on the cover of the end-box. The wire grill in end-box B was fitted perpendicularly to the runway. In addition three baffles were placed in the end-runway of that section, which forced a sort of snaky movement from the animals in contrast to the jumping movement necessitated by the hurdle in section A. The one-way door Y, leading from the runway to end-box B, was larger than the corresponding one in Section A and had a velvet black curtain attached to it on the inside.

The black curtain and the baffles, furthering on the one hand the perceptual differentiation of the two end-sections, also served the additional purpose of preventing light from the illuminated goal-box reaching the choice point area. To separate further the end-box cues from those provided at the choice point, two opaque screens 26 by 38 in. were set up between the initial runway and the end-sections, as shown in Fig. 1. Both end-sections were covered with black cloth. The only source of general illumination in the room came from a 150-watt bulb, mounted in a reflector directly behind the choice point, and facing upwards.

To test for any possible illumination differences at the choice point, photographs were taken of the choice point area under the actual illumination conditions of the experiment. Two strips of white paper were placed in the center of the choice point, facing 45 degrees to each side, and were photographed to indicate the difference in illumination at each side of the choice point. The photographs were later covered up with tape so that only the two strips were visible, and presented to judges who were asked to indicate which of the two sides was brighter. Judgments of 'equal' were permitted. Of 15 judges,

most of whom were psychology graduate students, but who were totally ignorant of the purpose of their judgments, 3 judged *A* brighter than *B*, 3 judged *B* brighter than *A*, and the remaining 9 judged them equal.

A test of possible temperature differences at the choice point was also made by the insertion of thermometers. No differences were found.

Animals

A total of 31 experimentally naive, male virgin rats from the U.C. laboratory, ranging in age from four to six months of M by M Tryon stock, were used for this experiment. All animals were placed on a 24-hour food deprivation schedule for several days prior to the onset of the experiment, and were fed daily about three a.m. on the regular dry food fed the colony.

Procedure

A. Preliminary Training

Prior to the actual experiment the animals were trained on a 28-in. straight alley, containing two white one-way doors, and leading to a goal box with a food container set into the far wall. The end-box used was essentially similar to those used in the maze proper, except that it was of intermediate width, 6 by 15 in., and contained no wire grill. The cover of the end-box was made of mesh wire, and the rats were run under ordinary conditions of room illumination—six overhead lamps providing the illumination of the room and the end-boxes for this phase of the experiment. The rats were all run under 24 hours of hunger. Each animal was run about four times nightly, for seven nights.

The food given to the animals in the end-boxes was in the form of small pellets, consisting of a mixture of their regular dry food, and some lactose added as a binding agent. Each of the pellets weighed 135 milligrams, and contained 10 parts of ordinary dry food to 4 parts of lactose. During this preliminary training situation the animals were permitted to consume as many pellets as they chose.

B. Procedure of Experiment Proper

Situation 1.—The animals were divided into two groups, run under 48 and 12 hours food deprivation respectively, on alternate mornings between 12:30 and 6 A.M. Each animal received two trials per experimental day, one free and one forced for nine experimental days. In the free trial, which was presented first each day, the animal chose whichever side it wanted. On the subsequent forced trial, the door (T or U) leading to the side chosen on the preceding free trial was locked.

Food was placed in both end-boxes. To insure equal food reinforcement on both sides, equal amounts of food were presented at all times—two pellets per trial for each animal.

The animals were given an upper limit of one hour to pass through the maze. If an animal failed to do so twice in succession, it was discarded from the experiment. In this manner 6 rats were lost, 4 from the 12 hour hunger group, and 2 from the 48 hour animals. The data presented are for the 25 rats remaining—13 rats in Group I (48 hours of hunger) and 12 in Group II (12 hours of hunger).

Situation 2.—About 26 hours following the completion of their ninth day's trials, all of the animals in each group were subjected to Situation 2—being shocked in one of the end-boxes. For this phase of the experiment, all animals were under a 24-hour hunger drive.

For this purpose, the entire end-sections A and B were removed from the maze and placed on *separate tables in another room.* The two tables were about five feet apart and arranged *at right angles to each other.* The sole illumination of the room was provided by the same lighting arrangement as was used in Situation 1, the light being mounted equidistant from each of the end-sections.

Each animal was first placed at the entrance of one of the end-sections, and received food when he reached the end-box. After a one-min. interval, he was then placed at the entrance of the other end-section, and received a violent electric shock about five sec. after he entered its end-box. He was detained in this end-box for one min., being shocked at intervals for a total of 20 sec. After about five min. he was placed in the same end-box again by hand, and was again shocked for 20 sec. out of a total 60 sec. of further detention there.

Half of the animals were shocked in end-box A and the other in end-box B. To equate for possible effects of position preferences, the free choices during the nine days of running in Situation 1 were tabulated. An index of side preference was then assigned to each animal on the basis of the total number of free runs to end-box B during those nine days. The animals in each of the two hunger-deprivation groups (12 hours and 48 hours) were then split into two sub-groups, one sub-group being shocked in end-box A and the other in end-box B, in such a manner that the average position preference was approximately the same for the two sub-groups within each main group.

Test situation.—Approximately two hours after completion of Situation 2, the animals were run again on the maze, set up exactly as in Situation 1, in the same room in which Situation

1 was conducted, and with the end-sections fitted back into place. All animals in both groups had been deprived of food for 26 hours, except for 2 pellets of food which had been consumed in the harmless end-box in Situation 2.

Results

In the test situation the great majority (22 out of 25) of the animals turned to the side opposite to that which contained the end-box they had been shocked in. Only three animals entered the wrong side at the choice point. One of these, an animal from Group I (48 hours of deprivation in the original learning situation), after having entered the wrong door at the choice point, squealed and started to bite and scratch at the door which it had just passed through, furiously trying to open it, managing eventually to squeeze through a slight clearing between the top of the door and the maze cover, and then dashed over to the correct side.

No particular difference was found in the test situation between Group I (48 hours of food deprivation in Situation 1) and Group II (12 hours of deprivation in Situation 1). Eleven out of 13 animals in Group I, and 11 out of 12 animals in Group II, made the correct turn at the choice point. Accordingly it was thought justifiable to combine the results of both groups for a test of significance. The probability of non-chance selection of the harmless side is indicated by a chi-square of 14.47, which is highly significant for one degree of freedom.

No particular distinguishing feature was noted for the three rats that ran to the wrong side. Neither their position preference, nor their time of running during the original training situation, yields any basis of differentiation from the rest of the animals.

Discussion

The results seem to indicate that the primary purpose of the experiment had been achieved. A situation was found, within which the discriminanda differences and relations are such as to be learned by rats, even though these differences are not differentially related to reinforcement. While it is true that the animals were rewarded in the maze, they were rewarded equally on both sides, so that neither the right nor the left turn was reinforced differentially. The fact that one end-box was lit up, contained baffles, etc., had no bearing on the reward received.

Of course it might be argued that the discriminanda differences of and by themselves constituted a reinforcement. A case for this is easily made, since at least some animals seemed to acquire position preferences for the one or the other side. Reinforcement theory would hold then that a particular turn became reinforced at the choice point, due to the animals' dislike of strong light, or of baffles, etc.

Nevertheless, this assumption does not explain the behavior of the animals during the test situation. For, even if the choice responses were differentially reinforced, we should only expect a continuation of the acquired preference, rather than the obtained shift to the harmless side. Furthermore, only about half of the animals showed any particular side preference, but even those animals that seemed to be indifferent to the sides, during the original training situation (Situation 1), made the correct choice during the test situation.

Of further interest is the fact that, due to the particular arrangement of the baffles in end-section B, the last

turning responses of the animals just before entering the end-box must be a right turn. The first trial in Situation 2 involved placing the animal at the beginning of the end-section, so that this turn had to be made just before entering the box and being shocked. By reinforcement theory, one might expect that this response, being followed by shock, would tend to be avoided. However, in the test situation, this response is precisely the one utilized by those animals that were shocked in end-box B. End-section B being located on the left of the choice point, a right turn was required to run towards the other side.

In short, the animals acted as if they had remembered that the bright, baffle-containing box was on the left, and the dark, hurdle-containing box on the right. It is obviously impossible to state which of the various available discriminanda differences were remembered by the animals. Nor is it our purpose now to determine in detail precisely what cues were responded to and noticed—the main point is that enough stimulus differences were provided so that the animals could notice something. Thus, it seems that the very general statement of the latent learning hypothesis presented above has been verified. And despite the extreme generality of this statement, it seems to us relatively difficult to envisage an interpretation derived from the reinforcement theory from which these same results could have been equally easily predicted.

It must be admitted, however, that as yet no specific predictions can be made concerning the nature of the factors under which latent learning will appear, and those under which it will not. Eventually, sign-Gestalt theory will have the responsibility of providing more specific sub-hypotheses which will predict such outcomes. Thus, the results of the present experiment, in establishing the occurrence of latent learning in one situation, point to the need of a program of systematic research to discover the essential factors that will facilitate or inhibit its occurrence in any situation.

While certain speculations can be made concerning the nature of these relevant variables, such speculations are as yet more in the nature of hunches than of adequate theoretical formulations. We would suspect, for example, that the degree of motivation of the animal, the presence of an appropriate goal-object when he is to learn the location of an inappropriate one, the perceptual outstandingness of the object to be learned and the ability of the rat to discriminate or not to discriminate his drives are all factors of importance in determining whether or not latent learning will occur. And the present experiment did in fact seek to test one of these more specific possibilities—namely that different degrees of motivation will in some degree determine whether or not latent learning is obtained. However, our results showed no differences between the 12-hour and the 48-hour groups. We would believe, however, that these findings of ours do not necessarily rule out the possibility of motivation effects in other experiments. Perhaps the present problem was too simple and hence obscured whatever results from the motivation differences might have otherwise have appeared. A further experiment is planned, utilizing an experimental situation that presents a greater problem to the animal—less markedly differentiated end-boxes and less experience in the maze.

Finally, all these considerations suggest a reinterpretation of the Spence and Lippitt and Kendler ex-

periments. Intended to demonstrate the non-existence of latent learning, they seem rather to point to a program of further research to determine more specifically under what conditions latent learning will and will not occur. Such further research would lead perhaps to more specific sub-hypotheses concerning the nature and genesis of sign-Gestalten.

It is to be recalled that some years ago Miller (8) performed an experiment which had features similar to ours, the results of which he explained in reinforcement terms plus the assumption of anticipatory goal-responses. Miller ran animals in a straight-away either to a food device or to a water device. The final movements necessary to obtain food or water were quite different in the two end-devices. In the food device the animals had to climb up and make a sharp turn to the right to secure food. In the water device they went straight in and made a sharp turn to the left. In the main experiment half of the animals were shocked in the food device in a separate position and half in the water device. When put back on the initial straight-away those animals which had originally run the straight-away to food and had been then shocked in the food device now ran more slowly than those others which had also originally run to food and had been then shocked in the water device. And comparable results were obtained for the two sub-groups that had been trained to water one of which was shocked in the water device and the other in the food device.

Miller explains his results by assuming that a component of the given goal-response of turning right for food or turning left for water for which the animal had originally been trained on the alley became conditioned to the stimuli presented along the course of the alley. He also assumes that the internal proprioceptive stimuli resulting from such goal-responses become part of the stimuli to which the avoidance response (due to the shock) become conditioned. Then, when the animals are put back in the original straight-away, the stimuli from this straight-away evoke an anticipatory element of the final goal-response. This anticipatory element of the conditioned goal-response produces its own proprioceptive stimulus consequences. These now evoke, due to the experience of having been shocked in the box, a conditioned avoidance response which latter expresses itself in the animals' now running more slowly down the alley.

An especial feature of Miller's argument is that the two very distinctive goal-responses made by the animals in the two end-boxes produce two very distinctive anticipatory goal-responses with two very different resultant proprioceptive stimuli. One of these sets of proprioceptive stimuli gets conditioned in the shock situation to avoidance and the other does not.

Now it must be admitted that our own experiment involved a somewhat similar set-up. The approach to end-box A involved a hurdle and the approach to end-box B involved baffles. Hence, Miller could argue that our rats also had acquired two different anticipatory goal-responses—one conditioned to the stimuli at door T and the other conditioned to the stimuli at door U; and that in the shocking experience those animals which were shocked in end-box A got the proprioceptive stimuli resulting from the A goal-responses conditioned to avoidance whereas the others, who were shocked in end-box B, got the proprioceptive stimuli resulting from the B goal-response conditioned to avoidance. Then when put back in the maze and coming to the choice point and releasing their anticipatory goal-responses the A-shocked group had avoidance evoked when they faced the stimuli of the right hand path and the B-shocked group had avoidance evoked when they faced the stimuli of the left hand path. We cannot altogether deny the possibility of such an explanation. Absolutely to settle the issue it would be necessary to repeat our experiment where the two end-boxes differed in 'perceptual' characters only and where absolutely no differences of goal response in

the two boxes would be involved. However, it may be noted that in Seward's experiment (see above, footnote 4) it was found that white and black goal boxes when the rats were fed in one and not in the other gave as positive latent learning results as did a pair of goal boxes which did produce different types of overt responses.

However, it may be asked what about blinking, pupillary reactions or the like? Is it possible to have a perceptual 'awareness' of any sort without concomitant motor responses? If it is Miller's (or Seward's) argument that there are such differentiating motor accompaniments for all perceptual processes, then these authors can perhaps hold, if they want to, that what we have called sign-Gestalten are based upon chains of minimal anticipatory responses going on at a very covert level. We, personally, are interested in the functional significance of latent learning and the resultant functional concept of sign-Gestalten and not in extremely hypothetical notions concerning the underlying neurology.

Summary

1. Twenty-five hungry pigmented M and M Tryon stock rats were run in a covered T maze to equal food reinforcements at the two ends of the T. The two end-sections were strongly differentiated. The end-boxes were of different size and one had a bright light shining into it and the other was dark. The two entrance sections to these end-boxes also differed. One had baffles and the other a hurdle, and the doors into the end-boxes were somewhat different in size and manner of being hinged.

2. After equal training on the two sides—one free trial and one forced trial per day for nine days—the two end-sections were placed in another room. Half of the rats were shocked in one of the end-boxes and half in the other.

3. When placed back on the maze 22 out of a total of 25 rats immediately avoided the side leading to the box in which they had just been shocked. In this test trial all animals were run under equal drive strength—i.e., 26 hours of food deprivation.

4. In the original training the total group had been divided into two motivation groups—one 48 hours hungry when originally trained in the maze and the other 12 hours hungry. No differences in the later avoidance of the side leading to the box in which the animals had been shocked appeared between the two motivation groups.

5. Our general theoretical position is that, although the Spence and Lippitt (10), Kendler (4), Kendler and Mencher (5) and Walker (14) experiments have indicated that 'latent learning' under the conditions of their experiments did not appear, this does not disprove the possibility of latent learning appearing under other conditions. All that the sign-Gestalt (or field expectancy) theory of learning assumes is that under some conditions, latent learning—that is learning which does not involve the differential reinforcement of responses—can nevertheless take place.

6. The present experiment seems to have provided such a set of conditions.

7. It is suggested that many further experiments varying such factors as the type of maze set-up, the amounts of initial training, degrees of motivation, forced or non-forced trials, the presence or absence of a reward object for the drive under which the animals are initially trained, and the like are needed in order to discover the precise conditions under which a non-differentially rewarded picking up of discriminanda and discriminanda re-

lationships (i.e., latent learning) will or will not tend to appear.

(Manuscript received December 14, 1948

References

1. Blodgett, H. C. The effect of the introduction of reward upon the maze performance of rats. *Univ. Calif. Publ. Psychol.*, 1929, 4, 113–134.
2. Honzik, C. H., & Tolman, E. C. The perception of spatial relations by the rat: a type of response not easily explained by conditioning. *J. comp. Psychol.*, 1936, 22, 287–318.
3. Hull, C. L. *Principles of behavior.* New York: D. Appleton-Century Company, 1943.
4. Kendler, H. H. An investigation of latent learning in a T-maze. *J. comp. physiol. Psychol.*, 1947, 40, 265–270.
5. Kendler, H. H., & Mencher, H.C. The ability of rats to learn the location of food when motivated by thirst. An experimental reply to Leeper. *J. exp. Psychol.*, 1948, 38, 82–88.
6. Leeper, R. W. The experiments by Spence and Lippitt and by Kendler on the sign-Gestalt theory of learning. *J. exp. Psychol.*, 1948, 38, 102–105.
7. Maier, N. R. F. Reasoning and learning. *Psychol. Rev.*, 1931, 38, 332–346.
8. Miller, N. E. A reply to "Sign-Gestalt or conditioned reflex?" *Psychol. Rev.*, 1935, 42, 280–292.
9. Seward, J. P. The minimum requirement for learning a maze discrimination. *Amer. Psychologist*, 1947, 2, 409.
10. Spence, K. W., & Lippitt, R. O. An experimental test of the sign-gestalt theory of trial and error learning. *J. exp. Psychol.*, 1946, 36, 491–502.
11. Tolman, E. C. *Purposive behavior in animals and men.* New York: The Century Co., 1932.
12. Tolman, E. C., & Honzik, C. H. Introduction and removal of reward and maze performance in rats. *Univ. Calif. Publ. Psychol.*, 1930, 4, 257–275.
13. Tolman, E. C. Cognitive maps in rats and men. *Psychol. Rev.*, 1948, 55, 189–208.
14. Walker, E. L. Drive specificity and learning. *J. exp. Psychol.*, 1948, 38, 39–49.
15. Walker, E. L. The acquisition of a response to food under conditions of food satiation. *Amer. Psychologist*, 1948, 3, 239. (Reported by title only)
16. White, R. K. The case for the Tolman-Lewin interpretation of learning. *Psychol. Rev.*, 1943, 50, 157–186.

ATTITUDINAL DETERMINANTS OF CONDITIONING AND OF GENERALIZATION OF CONDITIONING[1]

BY GREGORY RAZRAN

Queens College

Introduction

1. *Historical.*—It has been observed by CR experimenters with human *Ss* that a conditioned response formed to some stimulus will generalize to non-conditioned stimuli that are in some way related to the conditioned stimulus (1, 2, 6, 9, 16, 17, 20, 22–26, 35, 37–41, 43–48).[2] Moreover, a number of these experimenters (1, 2, 16, 17, 26) have maintained that their data warrant the postulation of a gradient of CR generalization that in Hull's words "is a monotonic decreasing function of the magnitude of the differences between the conditioned stimulus and the unconditioned [generalization] stimuli" (18, p. 133). The writer (42) has recently challenged, on the basis of an analysis of nearly all available evidence, the doctrine of a *quantitative continuous* gradient of CR generalization either in animal or in human *Ss*. His analysis did, however, reveal that (a) non-conditioned generalization stimuli do evoke CR's; (b) these generalization CR's are weaker—smaller magnitudes, longer latencies, lesser resistance to extinction—than conditioned CR's; and (c) some sort of a crude two- or three-step gradient—which, in the writer's view, is likely to correlate much more with general organic capacities and learned activities of the individual than with specific psychophysical relatednesses of the generalization stimuli to the conditioned stimulus along some stimulus dimension or dimensions—does obtain.

In 1935 and to a much lesser extent in 1936, the writer carried out a series of studies on attitudinal determinants of conditioned salivation in human *Ss* (32–34). He then found conditioning to be more effective when (a) the *Ss* were in a group rather than alone; (b) the conditioning was a constituent part of a larger more 'meaningful' task; (c) the *Ss* adopted, as inferred from a statistical analysis of their data and as checked by some introspection, a positive attitude towards the CR situation; (d) the *Ss* were told that a pair of to-be-conditioned nonsense syllables meant saliva in Benga, an African language; (e) the *Ss* were instructed to form associations between their to-be-conditioned stimuli and saliva. On the other hand, the writer's results showed (a) less effective conditioning when the *Ss* adopted, as inferred from a statistical analysis of their data and as checked by some introspections, a negative or an indifferent attitude towards the CR situation; (b) very little conditioning when the *Ss* were instructed not to form any associations between their to-be-conditioned stimuli and saliva; and, again, (c) less effective conditioning when (1) thinking of food or observing eating rather than actual eating was the unconditioned stimulus and when (2) a word or a nonsense syllable or a digit rather than a sound of a metronome was the conditioned stimulus.

[1] This study was prepared for publication while the writer was a Fellow of the John Simon Guggenheim Memorial Foundation.

[2] In order not to encumber the bibliography only a few Russian references on this topic are included.

The writer's specific findings on the role of attitudes in human conditioning were in the main corroborated and expanded—allowances being made for differences probably due to differences in UR's and setups—by CR investigators of the (a) eyelid response (Hilgard and associates, **11**, **13–15**; J. Miller, **29**; Miller and Cole, **30**; Cole, **4**; Marquis and Porter, **28**; Grant, **8**; Humphreys, **19**); (b) GSR (Cook and Harris, **5**; Mowrer, **31**); (c) electric shock (Hilgard and Allen, **12**; Hunter, **21**); (d) sensory CR's (Bogoslovski, **3**; Ellson, **7**).

2. *The present problem.*—The present experiment is primarily an extension of the writer's interest in attitudinal determinants of CR's to the problem of CR generalization. However, the data on simple conditioning may also be of value as checks on previous findings by others and by the writer (*op. cit.*). The experiment was performed in 1939. But it seems to have added importance now in the wake of the recent controversy between Lashley and Wade (**27**) and Hull (**18**) concerning CR generalization, and Lashley's and Wade's suggestion that the Yale "experiments are open to the objections that they used adult human subjects for whom the stimulus series represented familiar relational sequences" and that such experiments "must rule out any tendency to identify a single stimulus as belonging in a familiar graded series or to use habits of relational thinking" (**27**, p. 75).

General CR Procedure

Each of the 21 *S*s—all college undergraduates—in the experiment formed a salivary CR to two stimuli: (a) a tone of *C* (66 cycles) emitted by a Stoelting *just* harmonium, and (b) the word *flower* flashed on a screen. The salivary CR was formed by presenting in one session the tone and in another the word 300 times during a training session consisting of 15 two-min. eating periods (pretzels, tea-sandwiches, lollipops, peppermint candy) separated by one- to two-min. rest intervals. There were altogether four such training sessions, two for the tone and two for the word, and they were followed by two training-testing sessions for the tone and by one training-testing session for the word. Each training-testing session consisted of four two-min. eating-conditioning periods during which the conditioned stimuli were again reinforced, and of four nine-min. testing periods during which the conditioned salivations to conditioned and to generalization stimuli were determined. There were altogether eight generalization stimuli for the tone: F, B, e, a, d^1, g^1, $c\sharp^2$, $f\sharp^2$; and four generalization stimuli for the words: 'flour,' 'glower,' 'shower,' and 'scour.' Each nine-min. testing period permitted the determination of the conditioned salivation to the conditioned stimulus and to two generalization stimuli, and each generalization stimulus was tested twice in the entire experiment for each *S*.

Conditioned salivation was determined by the writer's 'cotton technique,' which, as described in previous publications (**32**, **36**, **40**), consists of measuring saliva by weighing increments in dental cotton rolls (Johnson and Johnson, No. 3, 0.5 × 1.5 in.) inserted under the *S*s' tongues for short periods of time, usually for one min. Since the cotton-in-the-mouth is by no means itself an inactive stimulus, periods of control salivation must be rotated with periods of experimental salivation, and of course pre-training salivation to the to-be-conditioned stimuli must be determined. Again, to prevent evaporation, scale corrosion, and absorption, the rolls are first weighed in small cellophane envelopes and then re-weighed in the envelopes immediately after their removal from the *S*s' mouths. A special scale, constructed by A. Roller-Smith and Company of Bethlehem, Pa., permits instantaneous weighing accurately to two mgm.

Special Attitudes Procedure

The 21 *S*s in the experiment were divided into seven equal and equated groups, and the attitudes in each group were varied by means of instructions and information. The variations were:

1. *Group MC-MC.*—With this group a modified classical procedure was used for both conditioning and generalization. The *S*s were misinformed about the purpose of the experiment. They were told that the "experiment aims to study the effects of different degrees of hunger and satiety upon memory for tones and words," and were actually given a few 'sham' memory tests for these stimuli. At no time were the *S*s

in this group aware of attempts to condition them nor gave any evidence that they thought that the conditioned or the generalization stimuli were supposed to produce extra salivation. They all believed that *E*'s measuring their saliva was merely a means of ascertaining the degrees of their hunger. On the other hand, the *S*s in this group were very attentive to the stimuli in the CR situation and no doubt also to the responses and to their own physiological and mental states. Their attitudes were merely diverted to another task.

2. *Group MC-KR.*—The procedure for simple conditioning in this group was the same as that in the preceding group. But, before being tested for tone generalization, the *S*s in this group were given orally the following instructions: "When you hear a tone in this session, try to think of its relatedness to the tone with which we experimented the last two sessions. Try to think whether the tone that you will hear is higher or lower and how much higher and how much lower than the tone with which we experimented." The instructions for word generalization were similar, except that the *S*s were told not to pay any attention to word relatedness in meanings but only to those of sound and spelling, and that the words 'higher' and 'lower' in the instructions were replaced by 'similar' and 'dissimilar.' Thus, while the *S*s in this group were, like the *S*s in the preceding group, unaware of the CR relationships between stimuli, they were, unlike those *S*s, highly cognizant of the graded relatedness of the generalization stimuli to the conditioned stimuli.

3. *Group MC-VF.*—The simple conditioning procedure was again the same as that in the first group. But, before being tested for tone generalization, the *S*s in this group were instructed as follows (with modified corresponding instructions for word generalization): "I'd like to see how well you can control your reactions. You were conditioned to secrete saliva to a low tone on this instrument [conditioning explained at some length, and tone demonstrated]. From now on, you will hear eight higher tones, each about two or three musical intervals higher than the other, and it is your task to secrete most saliva to the tone closest to the conditioned tone —less, though, than to the conditioned tone itself—and least saliva to the tone most removed from the conditioned tone [all eight tones are now demonstrated]. In other words, I would like you to build up a saliva scale that will correspond as closely as possible to the scale of tones here." The *S*s in this group thus attempted through motivated voluntary effort to aid the formation of a gradient of CR generalization or, if such a gradient did not automatically obtain, to create one.

4. *Group MC-VI.*—Again, the procedure for simple conditioning was the same as that in the first group. But the instructions for tone generalization were (with correspondingly modified instructions for word generalization): "I'd like to see how well you can control your reactions. You were conditioned to secrete saliva to a low tone on this instrument [conditioning explained at some length, and tone demonstrated]. From now on, you will hear eight other tones, higher than the conditioned tone, but it is your task to secrete an equal amount of saliva in response to each tone irrespective of the pitch or quality of the tone." Here the *S*s were obviously told to counteract through motivated voluntary effort any CR gradient tendency that might have resulted automatically from the conditioning.

5. *Group KR-KR.*—The instructions for simple conditioning in this group were: "This is an experiment in the pairing of stimuli and reactions. While you will be eating, a tone will be sounded or a word will be flashed on the screen, and I would like to know what will happen later on when I will only sound the tone or flash the word. A famous physiologist found that if a bell is sounded a number of times while a dog is being fed, the sound of the bell begins to produce by itself saliva in the dog. But physiologists and psychologists do not agree about this in the case of human beings, and I would like to find out. It of course does not matter to me what the findings will be." The instructions for CR generaliztion were the same as those for Group MC-KR. The *S*s in this group thus had full knowledge of the stimulus relations in the CR situation and of the relations of the generalization stimuli to the conditioned stimuli, but did not know what was expected of them.

6. *Group VF-VF.*—The instructions for simple conditioning in this group were: "While you will be eating, a tone will be sounded or a word will be flashed on the screen, and I want you to connect in your mind the tone and the word with eating, so that when you hear or think of the tone, or see or think of the word, you will also think of eating." The instructions for CR generalization were the same as those in Group MC-PV. Both conditioning and generalization of conditioning were thus reinforced by motivated voluntary effort in this group.

7. *Group VI-VI.*—The instructions for simple conditioning were: "I'd like to see how well you can control your reactions. While you will be eating, a tone will be sounded or a word will be flashed on the screen, and I want you *not* to connect in your mind the tone and the word with eating, so that when you hear or think of the tone, or see or think of the word, you *will not* think of eating." The instructions for general-

ization were: "Despite your effort, you were conditioned to secrete saliva to the tone and to the word [conditioning explained at some length]. However, I would like to see again how well you can control your reactions in a different situation. From now on, you will hear eight other tones, higher than the conditioned tone, and four different words, and it is your task to see that you secrete an equal amount of saliva in response to each tone irrespective of its pitch and quality and in response to each word no matter what it be." Both conditioning and generalization of conditioning were thus counteracted by the *Ss*' motivated voluntary efforts.

As seen from the preceding paragraphs, four types of instructions were used by *E* and presumably four types of attitudes were induced in the *Ss*, with regard to both conditioning and generalization of conditioning. Theoretically, it would have been possible to match each of the four modes of conditioning with each of the four modes of testing for generalization, and to obtain 16 combinations. As it is, one mode of conditioning, modified classical (MC), was followed by four different modes of testing for generalization: modified classical (MC), knowledge of stimulus relations (KR), voluntary facilitation (VF), and voluntary inhibition (VI)—while three of the four modes of testing for generalization (KR, VF, VI) were experimented with twice, once with modified classical conditioning, once with their corresponding conditioning attitudes (MC-KR, KR-KR; MC-VF, VF-VF; MC-VI, VI-VI).

Results

The results are presented in Tables I–IV. Table I contains the main data on conditioning and generalization for the tone, and Table II those for the word, for each of the seven groups of *Ss*. In either table the conditioning is given in mgm. of conditioned saliva per two min., and the generalization in percents, that is, the conditioned salivation to the generalization stimuli as percents of the conditioned salivation to the conditioned stimuli. Tables III and IV permit summary, if not too precise, quantitative comparisons between the generalization gradients of the seven groups. They specify in each case the (a) magnitude of the gradient, as determined by the differences between the lowest and the highest conditioning due to generalization; and (b) the means and SD's of the gradient steps, or the differences in conditioning between adjacent generalization stimuli (excluding reversals). The tables also detail in each case (c) the number of reversals,

TABLE I

Attitudinal Determinants of Salivary Conditioning and of the Generalization of Salivary Conditioning to Sensory Stimuli

The *Ss* were 21 college undergraduates and the conditioned stimulus was the sound of *C* on a harmonium. The attitudes were: VF—voluntary-facilitatory, VI—voluntary-inhibitory, KR—knowledge of stimulus relations, and MC—modified classical. The first pair of letters in the first column refer to attitudes during conditioning, and the second pair to attitudes during generalization. Each conditioning entry is a mean of 24, and each generalization entry, a mean of 6 determinations (respectively, 8 and 2 determinations from each of 3 *Ss*).

Induced Attitude	Mgm. Saliva per 2 Min.	Percent of Generalization to Generalization Stimuli							
		F	*B*	*c*	*a*	d^1	g^1	$c\sharp^2$	$f\sharp^2$
MC-MC	341±20.1	67	49	54	42	40	32	41	38
MC-KR	367±24.7	62	54	50	41	34	40	32	31
MC-VF	318±26.5	64	52	44	50	39	40	30	24
MC-VI	398±24.8	78	72	76	74	56	58	42	48
KR-KR	256±25.7	66	61	50	46	52	46	32	30
VF-VF	587±22.3	70	64	72	51	53	43	41	34
VI-VI	184±29.0	76	72	78	68	52	54	59	42

TABLE II

ATTITUDINAL DETERMINANTS OF SALIVARY CONDITIONING AND OF THE GENERALIZATION OF SALIVARY CONDITIONING TO VERBAL STIMULI

The *S*s were 21 college undergraduates and the conditioned stimulus was the word *flower* flashed on a screen. The attitudes were: VF—voluntary-facilitatory, VI—voluntary-inhibitory, KR—knowledge of stimulus relations, and MC—modified classical. The first pair of letters in the first column refers to attitudes during conditioning, and the second pair to attitudes during generalization. Each conditioning entry is a mean of 24, and each generalization entry, a mean of 6 determinations (respectively, 8 and 2 determinations from each of 3 *S*s).

Induced Attitude	Mgm. Saliva per 2 Min.	Percent of Generalization to Generalization Stimuli			
		Flour	*Glower*	*Shower*	*Scour*
MC-MC	316±19.4	39	29	32	19
MC-KR	357±18.7	54	41	45	28
MC-VF	381±24.8	62	68	52	23
MC-VI	404±21.5	68	72	60	48
KR-KR	165±25.9	45	52	40	22
VF-VF	653±30.1	50	49	58	36
VI-VI	105±21.6	61	54	57	41

(d) the combined magnitude of the reversals in percents, and (e) a comparison of the magnitude of the gradients with the magnitude of the reversals, expressed as a gradient/reversal ratio. Finally, they offer (f) an estimate of the number of statistically reliable gradient steps that might be obtained if CR results of adjacent generalization stimuli were combined. Table III deals with tone generalization and Table IV with word generalization.

The data on simple conditioning in

TABLE III

THE EFFECTS OF ATTITUDES UPON THE GRADIENT OF GENERALIZATION OF SALIVARY CONDITIONING OF 21 COLLEGE UNDERGRADUATES CONDITIONED TO THE SOUND *C* ON A HARMONIMUM

The generalization stimuli were: *F*, *B*, *e*, *a*, d^1, g^1, $c\sharp^2$, and $f\sharp^2$. The attitudes were: VF—voluntary-facilitatory, VI—voluntary-inhibitory, KR—knowledge of stimulus relations, and MC—modified classical. All entries are in percents of generalization, that is, the conditioned salivation to the generalization stimuli as percents of the conditioned salivation to the conditioned stimuli.

Induced Attitude	Magnitude of Gradient	No. of Reversals	Magnitude of Reversals	Gradient/ Reversal Ratio	Mean and SD of Gradient Steps	Estimated No. of Reliable Gradient Steps
MC-MC	35	2	14	2.5	6.6; 3.6	Three
MC-KR	31	1	4	7.75	6.2; 2.7	Three or Four
MC-VF	40	2	7	5.7	8.6; 1.3	Three or Four
MC-VI	36	3	12	3.0	10.5; 6.7	Two or Three
KR-KR	36	1	6	6.0	6.7; 3.9	Three
VF-VF	36	2	10	3.6	10.2; 5.5	Three or Four
VI-VI	34	3	13	2.6	8.75; 6.2	Two

TABLE IV

THE EFFECTS OF ATTITUDES UPON THE GRADIENT OF GENERALIZATION OF SALIVARY CONDITIONING OF 21 COLLEGE UNDERGRADUATES CONDITIONED TO THE WORD *FLOWER* FLASHED ON A SCREEN

The generalization stimuli were the words: *flour*, *glower*, *shower*, and *scour*. The attitudes were: VF—voluntary-facilitatory, VI—voluntary-inhibitory, KR—knowledge of stimulus relations, and MC—modified classical. All entries are in percents of generaliztion, that is, the conditioned salivation to the generalization stimuli as percents of the conditioned salivation to the conditioned stimulus.

Induced Attitude	Magnitude of Gradient	No. of Reversals	Magnitude of Reversals	Gradient/ Reversal Ratio	Mean and SD of Gradient Steps	Estimated No. of Reliable Gradient Steps
MC-MC	20	1	3	6.7	11.5; 1.5	Three
MC-KR	26	1	4	6.5	15.0; 2.0	Three
MC-VF	45	1	6	7.5	22.5; 6.5	Three
MC-VI	34	1	4	6.0	12.0; 0.0	Three
KR-KR	30	1	7	4.3	15.0; 3.0	Three
VF-VF	22	1	9	2.4	11.5; 10.5	Three
VI-VI	20	1	3	6.7	11.5; 4.5	Three

the second column of Tables I and II might be examined first. They show conditioning to be highest in magnitude and lowest in variability in Group VF in which the *S*s were specifically instructed to form associations between the stimuli-to-be-conditioned and eating. Next comes Group MC in which the *S*s' attitudes were diverted to another task and they were not aware of *E*'s attempt to condition them. Least conditioning was obtained in Group VI in which the *S*s were told *not* to form any connections between the stimuli-to-be-conditioned and eating, and the results of Group KR, in which the *S*s were informed about conditioning in animals but told that anything might happen in human beings, were only a little better. All *t*'s between groups (but not between the several MC groups) are significant with *P* equalling .05. The fact that the instructions in Group VI did not wholly prevent the formation of the salivary CR is in line with the findings of Hilgard and Humphreys (15) and of J. Miller (29) and at variance with the older findings of the writer (32). However, it should be pointed out that antagonistic voluntary attitudes have been reported to nullify CR's in the GSR and in finger withdrawal (5, 21) and that supporting voluntary attitudes in this experiment, Group VF, have by no means been as facilitatory as found by Hilgard and Humphreys and by J. Miller (*op. cit.*). No doubt the nature of the unconditioned response, the degree of its integration with the individual's total activity stream and the degree of its voluntary control, the hedonic tones of producing and preventing the response, and the special setups of each experiment are factors that might account for the variations.[8]

[8] The statement by Cook and Harris (5, p. 209) that "The actual presentation of a series of inadequate-adequate stimuli combinations did not increase the strength of the conditioned response beyond the strength following the verbal associations made during the instructions" should certainly not be generalized to responses other than the GSR, and it needs rechecking for the GSR, too. Their use of the term *verbal conditioning* for their type of procedure is also not to be recommended, since this term has been used for situations in which the conditioned stimuli were verbal. *Instructional conditioning* (cf. Haggard, 10) is here appropriate, while *voluntary conditioning* might be reserved for procedures in which there are repeated

Going over to the main data of the experiment, those on CR generalization, we find considerably less variation among the various groups of *Ss*. Group MC-MC, the standard group, manifested a crude gradient of CR generalization that, upon analysis, is comparable to the gradients brought forth by Pavlov's laboratories and by the Yale studies (42). Groups MC-VF, VF-VF, MC-KR, and KR-KR yielded a little better gradient, and Groups MC-VI and VI-VI, on the whole, a little poorer gradient. *But in no case was the gradient of salivary production able to keep pace with the Ss' discriminative ability, namely, to attain eight reliable steps for tone generalization and four reliable steps for word generalization; and in all cases there was at least one reversal. On the other hand, no S was able, through voluntary effort, to reduce the gradient below two steps.* If the generalization steps were reduced by combining data from adjacent steps, there would result two reliable steps for the voluntary-inhibitory groups and three or four steps for the voluntary-facilitatory and 'knowledge of stimulus relations' groups.[4]

Discussion and Interpretation

The comparatively small effects of voluntary and conscious attitudes upon the gradient of CR generalization call obviously for some interpretation. And upon some reflection, the interpretation appears to be rather simple. It is all a matter of capacity and past training. Apparently, while a human *S* may readily produce or reduce or even totally prevent 'at will' his conditioned salivation (or some other comparable conditioned response), he cannot so readily fractionate 'at will' this salivation to an extent that would correspond to the many degrees of relatedness of the generalization stimuli to the conditioned stimuli. His sensory-perceptual capacities are merely much finer than his control of their motor and glandular outlets. This does not mean that fractionations finer than those obtained in this experiment are impossible or even difficult. In one experiment (34) the writer produced five differential salivary responses that were statistically reliable while he was thinking of saliva in six different languages with which he was differently familiar. And there is no doubt that the writer's *Ss* could have in time improved considerably their fractionating abilities. But apparently they could not do so in a few trials, and apparently *Ss* do not do so in typical experiments on CR generalization.

The fact that the *Ss*' voluntary efforts did not change much their gradients of CR generalization may lead some students of this problem to conclude that these gradients—and similar gradients obtained by other CR experimenters—are wholly reflexive or involuntary or peripheral or 'just conditioned' in nature. But this does not really follow, since one may equally argue that all CR generalization is attitudinally controlled so that added instructions only modify it but do not change it radically. In a previous article (42) the writer suggested that when *Ss* conditioned to some stimulus or object are confronted with some new non-conditioned but in

pairings of conditioned stimuli with voluntary responses, as in the study by Marquis and Porter (28).

[4] It might also be added that in CR generalization (a) there were hardly any differences between the effectiveness of voluntary-facilitatory and voluntary-inhibitory attitudes, and (b) other things being equal, verbal conditioned stimuli yielded better gradients than sensory conditioned stimuli.

some way related stimulus or object, they categorize or rate the new stimulus or object on some sort of crude similarity-dissimilarity scale, and that these categorizing or rating attitudes control or even initiate the generalization response. The writer's suggestion was based upon (a) the crude two- or three-step gradient which he invariably obtained by analyzing a variety of data on CR generalization, and (b) the introspections of some of his *S*s. Other *S*s, however, failed to report such introspections, and it appears now to the writer that such categorizing behavior may in time well become automatic, an integral part of the individual's learned habits and capacities, and barely conscious. If this be so, then it should not be difficult to understand (a) why this categorizing behavior and its motor and glandular outlets are not readily nullified by conscious negative or antagonistic attitudes, and (b) why it should require considerable training to convert its crude steps into a refined multi-step gradient. To put it somewhat differently, it is the writer's contention that present evidence warrants the assumption that CR generalization is much more a function of *automatized* attitudes than of *automatic* reflexive or conditioned reflexive reactions.

Summary

1. The salivary responses of 21 college undergraduates were first conditioned to (a) the sound of *C* on a Stoelting *just* harmonium, and (b) the sight of the word *flower* flashed on a screen; and then tested for CR generalization with (a) tones *F*, *B*, *e*, *a*, d^1, g^1, $c\#^2$, $f\#^2$, and (b) words 'flour,' 'glower' 'shower,' and 'scour.'

2. By means of instructions three specific attitudes were induced in the *S*s with respect to the conditioning and the generalization: (a) a voluntary-facilitatory, (b) a voluntary-inhibitory, and (c) a cognitive (knowledge of stimulus relations). In addition, a fourth mode of conditioning and generalization was used in which the *S*s were misinformed about the nature of the experiment and their attitudes diverted to another task.

3. Simple conditioning was most effective with a voluntary-facilitatory attitude and least effective with a voluntary-inhibitory attitude. A cognitive 'mere-knowledge-of-stimulus-relations' attitude was less effective than a mode of conditioning in which the *S*s' attitudes were diverted to another task.

4. Voluntary and cognitive attitudes did not change radically the *S*s' gradients of CR generalization. No *S*'s voluntary effort was able to produce a gradient of more than four steps with eight widely differing tones, and, similarly, no *S* was able to reduce the gradient below two steps. The gradient consisted roughly of three steps in the *S*s whose attitudes were diverted to another task.

5. Evidence is presented to suggest that the recalcitrance of CR generalization to the influences of voluntary and cognitive attitudes is due not so much (a) to its reflexive automatic nature as (b) to automatized categorizing attitudes, namely, the tendency of *S*s conditioned to some stimulus to categorize or rate new nonconditioned stimuli on some sort of a crude similarity-dissimilarity scale.[5]

6. There is some evidence to suggest that, other things being equal, gradients of CR generalization in human *S*s are more readily formed

[5] In the writer's opinion, there is no discrepancy between the results of the present study and those of another study by the writer (41) in which attitudes affected greatly CR generalization, since the attitudes in the latter study aided, rather than interfered with, the *S*s' *habits* of categorizing.

with verbal than with sensory conditioned stimuli.

(Manuscript received January 27, 1949)

References

1. Bass, M. J. The irradiation of a tactile conditioned reflex in man. *J. comp. Psychol.*, 1934, **17**, 47–65.
2. Bekhterev, V. M. *General principles of human reflexology*. New York: International, 1932.
3. Bogoslovski, A. I. An attempt at creating sensory conditioned reflexes in humans. *J. exp. Psychol.*, 1937, **21**, 403–422.
4. Cole, L. E. A comparison of the factors of practice and knowledge of experimental procedure in conditioning the eyelid response in human subjects. *J. gen. Psychol.*, 1939, **20**, 349–373.
5. Cook, S. W., & Harris, R. E. The verbal conditioning of the galvanic skin reflex. *J. exp. Psychol.*, 1937, **21**, 202–210.
6. Diven, K. Certain determinants in the conditioning of anxiety reactions. *J. Psychol.*, 1937, **3**, 291–308.
7. Ellson, D. G. Experimental extinction of an hallucination produced by sensory conditioning. *J. exp. Psychol.*, 1941, **28**, 350–361.
8. Grant, D. A. The influence of attitude on the conditioned eyelid response. *J. exp. Psychol.*, 1939, **25**, 333–346.
9. Grant, D. A., & Schneider, D. E. Intensity of the conditioned stimulus and strength of conditioning: I. The conditioned eyelid response to light. *J. exp. Psychol.*, 1948, **38**, 690–697.
10. Haggard, E. A. Experimental studies in affective processes: I. Some effects of cognitive structure and active participation on certain autonomic reactions during and following experimentally induced stress. *J. exp. Psychol.*, 1943, **33**, 257–285.
11. Hilgard, E. R. An algebraic analysis of conditioned discrimination in man. *Psychol. Rev.*, 1938, **45**, 472–496.
12. Hilgard, E. R., & Allen, M. K. An attempt to condition finger reactions based on motor point stimulation. *J. gen. Psychol.*, 1938, **18**, 203–207.
13. Hilgard, E. R., *et al.* Conditioned discrimination: the development of discrimination with and without verbal report. *Amer. J. Psychol.*, 1937, **49**, 564–580.
14. Hilgard, E. R., *et al.* Conditioned discrimination: the effect of knowledge of stimulus relationships. *Amer. J. Psychol.*, 1938, **51**, 498–506.
15. Hilgard, E. R., & Humphreys, L. G. The effect of supporting and antagonistic voluntary instructions on conditioned discrimination. *J. exp. Psychol.*, 1938, **22**, 291–304.
16. Hovland, C. I. The generalization of conditioned responses: I. The sensory generalization of conditioned responses with varying frequencies of tone. *J. gen. Psychol.*, 1937, **17**, 125–148.
17. Hovland, C. I. The generalization of conditioned responses: I. The sensory generalization of conditioned responses with varying intensities of tone. *J. genet. Psychol.*, 1937, **51**, 271–291.
18. Hull, C. L. The problem of primary stimulus generalization. *Psychol. Rev.*, 1947, **54**, 120–134.
19. Humphreys, L. G. The effect of random alternation of reinforcement on the acquisition and extinction of conditioned eyelid reactions. *J. exp. Psychol.*, 1939, **25**, 141–158.
20. Humphreys, L. G. Generalization as a function of method of reinforcement. *J. exp. Psychol.*, 1939, **25**, 361–372.
21. Hunter, W. S. An experiment on the disinhibition of voluntary responses. *J. exp. Psychol.*, 1938, **22**, 419–428.
22. Kapustnik, O. P. The interrelation between direct conditioned stimuli and their verbal symbols. *Trud. Labor. Fiziol. pri Leningr. Pedagog. Inst. Gertzena.* 1930, **2**, 11–22.
23. Keller, M. Mediated generalization: the generalization of a conditioned galvanic skin response established to a pictured object. *Amer. J. Psychol.*, 1932, **56**, 438–448.
24. Kotliarevsky, L. I. The formation of pupillary conditioned reflexes and of a differentiation in response to both direct and verbal stimuli. *Arkh. Biol. Nauk*, 1935, **39**, 477–489.
25. Kotliarevsky, L. I. Cardio-vascular conditioned reflexes to direct and verbal stimuli. *Fiziol. Zh. S.S.S.R.*, 1936, **20**, 228–242.
26. Krasnogorski, N. I. Bedingte und unbedingte Reflexe im Kindesalter und ihre Bedeutung für die Klinik. *Ergebn. inn. Med. Kinderhk.*, 1931, **39**, 613–730.
27. Lashley, K. S., & Wade, M. The Pavlovian theory of generalization. *Psychol. Rev.*, 1946, **53**, 72–87.

28. Marquis, D. G., & Porter, J. M., Jr. Differential characteristics of conditioned eyelid responses established by reflex and voluntary reinforcement. *J. exp. Psychol.*, 1939, **24**, 347–365.
29. Miller, J. *The effect of facilitatory and inhibitory attitudes on eyelid conditioning.* Unpublished Ph.D. thesis, Yale, 1939.
30. Miller, J., & Cole, L. E. The influence of a "voluntary" reaction upon the development and the extinction of the conditioned eyelid reaction. *J. genet. Psychol.*, 1936, **48**, 405–440.
31. Mowrer, O. H. Preparatory set (expectancy)—a determinant in motivation and learning. *Psychol. Rev.*, 1938, **45**, 62–91.
32. Razran, G. Conditioned responses: an experimental study and a theoretical analysis. *Arch. Psychol., N. Y.*, 1935, **28**, No. 191.
33. Razran, G. Attitudinal control of human conditioning. *J. Psychol.*, 1936, **2**, 327–337.
34. Razran, G. Salivating and thinking in different languages. *J. Psychol.*, 1936, **1**, 145–151.
35. Razran, G. Studies in configural conditioning: VII. Ratios and elements in salivary conditioning to various musical intervals. *Psychol. Rec.*, 1938, **2**, 370–375.
36. Razran, G. Studies in configural conditioning: II. The effect of subjects' attitudes and of task sets upon configural conditioning. *J. exp. Psychol.*, 1939, **24**, 95–105.
37. Razran, G. A quantitative study of meaning by a conditioned salivary technique (semantic conditioning). *Science*, 1939, **90**, 89–90.
38. Razran, G. Studies in configural conditioning: V. Generalization and transposition. *J. genet. Psychol.*, 1940, **56**, 3–11.
39. Razran, G. Sentential and propositional generalizations of salivary conditioning to verbal stimuli. *Science*, 1949, **109**, 447–448.
40. Razran, G. Semantic and phonetographic generalizations of salivary conditioning to verbal stimuli. *J. exp. Psychol.*, 1949, **39**, 342–352.
41. Razran, G. Some psychological factors in the generalization of salivary conditioning to verbal stimuli. *Amer. J. Psychol.*, 1949, **62**, 247–256.
42. Razran, G. Stimulus generalization of conditioned responses. *Psychol. Bull.*, 1949, **46**, 337–365.
43. Riess, B. F. Semantic conditioning involving the G.S.R. *J. exp. Psychol.*, 1940, **26**, 238–240.
44. Riess, B. F. Genetic changes in semantic conditioning. *J. exp. Psychol.*, 1946, **36**, 143–152.
45. Smolenskaya, O. P. Verbal symbols of conditioned and differential stimuli. *Na Put. Izuch. Vyssh. Form Neirodin. Reb.*, 1934, 304–315.
46. Traugott, N. N. The interrelations of immediate and symbolic projections in the process of formation of conditioned inhibition. *Na Put. Izuch. Vyssh. Form Neirodin., Reb.*, 1934, 273–303.
47. Watson, J. B., & Raynor, R. Conditioned emotional reactions. *J. exp. Psychol.*, 1920, **3**, 1–14.
48. Wickens, D. D. Studies of response generalization: I. Stimulus generalization during response generalization. *J. exp. Psychol.*, 1943, **33**, 221–227.

THE FORMATION AND RETENTION OF REMOTE ASSOCIATIONS IN ROTE LEARNING[1]

BY JOHN T. WILSON

Office of Naval Research

INTRODUCTION[2]

Remote associations in rote learning furnish important clues as to the nature of the organizational process occurring in both memorization and retention. The circumstances under which they are formed and the rate of their subsiding enter importantly into several contemporary learning theories.

The purpose of the present study was to investigate remote associations within serial lists of adjectives as a function of: (a) degree of learning; (b) spaced *vs.* massed practice; and (c) length of interval between the attainment of a specified criterion and a recall test.

The conditions along these three basic dimensions were:

(a) *Degrees of learning*: Four degrees of learning were employed, 50, 75, 100 and 200 percent perfect anticipation.

(b) *Variations in spacing between trials during practice*: Three conditions of practice were utilized, namely, 6, 30, and 60 sec. spacing between trials.

(c) *Lengths of interval between criterion and recall*: Four intervals between learning and the recall test were used, these being 0, 2, 5, and 20 min. delay.

Conditions under (a) were included in the experimental design for the purpose of yielding systematic information concerning the formation of remote associations during serial learning. Conditions under (b) and under (c) were included as a basis for testing McGeoch's hypothesis of a faster rate of forgetting for remote associations as compared with adjacent, or correct, associations (16, pp. 142–147).

Briefly stated, the McGeoch hypothesis is that during the memorization of a serial list, a subject learns not only correct responses but also incorrect and conflicting responses, of which remote associations are a major portion. These conflicting response tendencies are thought to interfere with the appearance of correct responses. However, following cessation of practice, the interfering responses, which are assumed to be less well-fixated, suffer a more rapid decrement in strength than do the relatively highly reinforced adjacent, or correct, responses.

McGeoch supports the hypothesis with data from studies of distributed practice, serial position effects, and of reminiscence (16, pp. 142 ff. and 350 ff.). Findings of fewer repeated maze errors under distributed practice than under massed practice (11, 12), and of the superiority of wider forms of distributed practice in activities which

[1] This report is based on a dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Stanford University, June 1948. The research was conducted during the author's tenure of a National Research Council predoctoral fellowship, and under the direction of Professor E. R. Hilgard. Thanks are due to Professor Hilgard and to Dr. B. J. Underwood for reading the manuscript.

[2] For a complete discussion of remote associations, method for studying them, and theories to account for them, see McGeoch (16, Chap. III). Later experimental papers not covered in McGeoch are (1) and (20).

generate excessive amounts of conflicting responses (14), are especially to the point. The results of Hovland's (7, 8, 9) rote learning studies and of Ward's (19) reminiscence study are best interpreted, according to McGeoch, as being due to differential rates of forgetting of correct and interfering intra-list responses.

At the same time, McGeoch states his awareness that such an hypothesis must necessarily be highly tentative in view of the lack of systematic information concerning the formation and functioning of remote associations. It is toward the end of furnishing additional empirical information on the formation of remote associations that the present experiment is aimed. In addition, we have attempted an experimental test of McGeoch's hypothesis of a faster rate of forgetting of remote as compared with correct associations.

The Experiment

General plan.—The general plan of the experiment is that of a triple classification factorial design, employing analysis of variance. Combining the indicated experimental conditions in all possible ways produces 48 conditions. With three *S*s per condition, there are eight independent sources from which to estimate the population variance. These sources and their respective degrees of freedom are:

Source	*df*
1. Degrees of learning	3
2. Conditions of spacing	2
3. Intervals following learning	3
4. Interaction 1 × 2	6
5. Interaction 1 × 3	9
6. Interaction 2 × 3	6
7. Interaction 1 × 2 × 3	18
8. Within conditions	96
Total	143

Procedure.—The method employed for measuring remote associations was the *association method*, described in detail in McGeoch (16, p. 86).

One practice day, to familiarize *S*s with learning and recall instructions, preceded one experimental session for each *S*. On the practice day, *S* learned to a one-perfect criterion a list of 16 nonsense syllables. *S* was then given an association test by presenting to him each of the nonsense syllables in the list, singly and in random order. In the single experimental session, which followed 24 hr. later, each *S* learned an assigned random order of 16 two-syllable adjectives, under experimental conditions specified for him, following which he was given an association test, using a new random order of the list learned.

All learning was by the anticipation method, with the items exposed serially on a Missouri-type memory drum. A 2-sec. exposure rate was used throughout all learning trials. In the recall test, each item was exposed in the same manner as during learning, except the exposure was continued only for the length of time necessary to elicit a response.

In order to attain a minimum of between-trial recitation, when learning was under conditions of spaced practice (30-sec. and 60-sec. spacing), colors were named by *S* from a color card. In the recall tests, *S*s were instructed to respond as quickly as possible with "the first word from the list that comes to mind." This differs slightly from the usual instruction in the association method, to respond with "the first word that comes to mind." Under those experimental conditions which included 2-, 5-, and 20-min. intervals between criterion and recall test, the time was spent by having *S* rate a series of cartoons for their "degree of humor to him."

Materials.—The learning material for the experimental session for each *S* was a list of 16 non-synonymous, two-syllable adjectives. The lists for all *S*s contained the same adjectives, each list being a different random order of the 16 items. The adjectives were drawn from a population of 62 non-synonymous, two-syllable adjectives, all of which had a scale value of 4.25 or above, on a 5-point scale of 'familiarity' (4). Selection was accomplished by first randomly choosing, from an alphabetical listing of the 62 adjectives, 23 which had different initial letters. The 16 items finally selected for use in the lists were selected from these 23.[1]

Forty-eight random orders of the 16 adjectives were then compiled and a different list was assigned by random to each of the experimental conditions, as the list to be learned under that condition. The 48 random orders of the list were then reassigned to each of the experimental

[1] Selection of adjectives, assignment to lists, and assignment of *S*s to conditions were all accomplished by utilization of tables of random numbers (3).

conditions, as the list to be used in the recall test under that condition.[4]

Subjects.—*Ss* in the experiment were 144 experimentally naive college students, 41 women and 104 men. All were enrolled in the course in elementary psychology at Stanford. Three *Ss* were assigned to each experimental condition and used but once, after the preliminary practice session. The purpose of the experiment was not revealed to any *S* until after the completion of his or her experimental session.

Method of scoring remote associations.—The measure of primary significance was the number of remote associations present at recall. This was determined by recording, on the experimental day, all of the responses of each *S* during the association test. Each response made was then categorized as being an adjacent forward (correct) association, or as being a remote association of some degree of remoteness. This categorization was determined by comparing the response elicited, to the adjective which followed the stimulus item eliciting the response, in the originally learned list. If the two were not identical, and if the response made was not from outside the list, the degree and direction of the response's remoteness were then determined by noting, in the list originally learned, the direction and the number of items removed the given response was from the stimulus item eliciting it. Adjacent backward responses were included in the remote association category.

The list was considered as a linear series, with the exception of responses between serial positions 16 and 1, and vice versa. In these two instances, an association from position 16 to position 1 was considered an adjacent forward association. An association from position 1 to position 16 was scored as a backward adjacent association. This departure from complete linearity was made for the purpose of eliminating an artificial inflation of remote associations of 14-degrees remoteness. The total number of such associations was small, and the outcome of the experiment would not have been changed had they been scored otherwise, or had they been eliminated from the data.

[4] The advantage of the technique for compiling lists is that it reduces to an experimentally achievable minimum the differential effects, from list to list, of any intra-list associations inherent in the items themselves, prior to practice. Chi-square tests of the response equivalence value of each item, with reference to the total number of times it was used by all *Ss* for both adjacent and remote associations, supported the hypothesis that the number of responses contributed by any one item did not differ significantly from what would be expected on a chance basis.

Results

Frequency of remote associations under all conditions.—In order to indicate the frequency of remote associations relative to the total frequency of associations made at recall, Table I shows the data *in toto*, simply as the number of remote associations made under the 48 conditions by 144 subjects. The frequencies of the three types of responses, forward adjacent, remote, and extraneous, are presented. With 144 *Ss* and 16-item lists, there is a maximum of 2304 responses possible at recall. Of this maximum, there were 1463 forward adjacent, or correct, associations, 740 remote associations, and 101 extraneous associations, i.e., either out-of-list responses or failures to respond. In terms of percentages, forward adjacent responses constituted 63.5 percent of the total, and remote associations constituted 32.1 percent. Extraneous responses comprised 4.4 percent of the total number of associations.

TABLE I

Frequency of Associations at Recall by Type

Type of Association	Frequency	Percent of Total
Adjacent forward associations	1463	63.5
Remote associations	740	32.1
Extraneous associations	101	4.4
Total	2304	100.0

Remote associations and the main variables.—Table II presents the analysis of variance, testing the effects of the three main variables upon remote associations. The *F*-ratios for all interaction terms are of non-significant magnitude. That for the three-way interaction is 1.14, with a value of 2.24 being necessary for significance at the .01 level. The three two-way interaction *F*-ratios are 0.83,

TABLE II

ANALYSIS OF VARIANCE OF FREQUENCY OF REMOTE ASSOCIATIONS AT RECALL

Source of Variance	Sums of Squares	*df*	Variance Estimate	*F*	*F* at .01
1. Total	1661.2223	143	11.6169		
2. Degrees of learning	497.3888	3	165.7963	21.02	3.98
3. Intervals following learning	9.4444	3	3.1488	0.40	3.98
4. Conditions of spacing	43.5972	2	21.7986	2.76	4.82
5. Interaction 2 × 3	112.6112	9	12.5124	1.59	2.59
6. Interaction 2 × 4	40.2362	6	6.7060	0.85	2.99
7. Interaction 3 × 4	39.1806	6	6.5301	0.83	2.99
8. Interaction 2 × 3 × 4	161.4305	18	8.9684	1.14	2.24
9. Within conditions	757.3334	96	7.8888		

0.85, and 1.59, with *F*'s of 2.99, 2.99, and 2.59, respectively, being necessary for significance at the .01 level. We may therefore accept the null hypothesis that the interaction of the three main variables, either in combination with each other or in triple combination, has not contributed a significant amount of variance to the means, over that due to individual differences and errors of measurement, as reflected in the within condition variance estimate. For testing the effects of the main variables upon the variances of the means of the measures, we are justified in using the within condition variance estimate, with its advantageously large number of degrees of freedom, as the denominator in the *F*-ratios. In all instances, the within condition term has been used without combining it with non-significant interaction terms.

Looking now at the *F*-ratios for testing the main effects, it may be seen that only in the case of degrees of learning is there a significant *F*. The *F*-values are: 21.02 for degrees of learning, 0.40 for intervals following learning, and 2.76 for conditions of spacing. Values of 3.98, 3.98, and 4.82, respectively, are necessary for significance at the one percent level. We may be confident, well beyond the .01 level, that with increasing degrees of learning, there is a significant reduction in the number of remote associations formed and retained. On the strength of the non-significant interactions between degrees of learning and the other two variables, we may also infer that such differences should be consistently found over the conditions of spacing and the lengths of interval following learning utilized in this experiment.

The differences among the means of the four degrees of learning, as tested for significance by the *t*-test, are presented in Table III. The mean number of remote associations at each of the four degrees of learning are as follows: 7.47 at the 50-percent criterion, 6.44 at the 75-percent criterion, 3.47 at the 100-percent criterion, and 3.17 at the 200-percent criterion. The *t*-values testing the significance of the mean differences are: 1.56 for the difference between the means of the 50-percent and the 75-percent criteria groups, 4.49 for the difference between the means of the 75-percent and the 100-percent criteria groups, and 0.45 for the difference between the means of the 100-percent and the 200-percent criteria groups. In each case a *t*-value of 1.98 is necessary for significance at the .05 level, and a value of 2.62 is necessary at the .01 level.

On the basis of these *t*-values we may infer that the significant re-

TABLE III

MEAN NUMBER OF REMOTE ASSOCIATIONS AT RECALL AND MEASURES OF THE SIGNIFICANCE OF MEAN DIFFERENCES

Variable and Conditions	Mean Remote Associations	t*
Degrees of learning:		
50 percent	7.47	$t_{50-75} = 1.56$
6 sec.	6.66	
30 sec.	8.58	
60 sec.	7.17	
75 percent	6.44	$t_{75-100} = 4.49$
6 sec.	6.00	
30 sec.	7.17	
60 sec.	6.17	
100 percent	3.47	$t_{100-200} = 0.45$
6 sec.	3.33	
30 sec.	4.75	
60 sec.	2.33	
200 percent	3.17	
6 sec.	2.42	
30 sec.	3.08	
60 sec.	4.00	
Intervals following learning:		F_{delay} not significant
0 min.	5.50	
2 min.	5.17	
5 min.	5.11	
20 min.	4.77	
Conditions of spacing:		$F_{spacing}$ not significant
6 sec.	4.60	
30 sec.	5.89	
60 sec.	4.92	

* t at .01 = 2.62; t at .05 = 1.98

duction in remote associations with continued practice comes between the 75-percent and the 100-percent levels of mastery. This fact has implications in regard to optimal conditions under which to study remote associations, in that criteria above 75-percent mastery would be expected to yield fewer remote associations than would lower degrees of learning. These data are also of interest with reference to the more general points as to what constitutes a satisfactory criterion of learning, in terms of freedom from intra-list interference, and as to what 'overlearning' may mean in this regard. For example, with reference to overlearning, the 200-percent criterion, defined herein as two successive perfect anticipations of the list, did not significantly reduce the amount of intra-list interference, as represented by remote associations, over that accomplished by a 100-percent criterion.

As for the means of the measures under the conditions of spacing and under the conditions of intervals following learning, those for the three conditions of spacing were: 4.60, 5.89, and 4.92 for the 6-sec., 30-sec. and 60-sec. spacings, respectively. Those for the intervals following learning were: 5.50 for the 0-min. interval group, 5.17 for the 2-min. interval group, 5.11 for the 5-min. interval group, and 4.77 for the 20-min. interval group. We have previously shown that, on the basis of the F-ratio for testing the significance of the overall differences among these means, we cannot reject the hypothesis that they are based upon random samples of measures from the same population. This being the case, testing the significance of mean differences is superfluous.

Analysis of extraneous responses.— Because of the heterogeneity of the extraneous response category, and also because these responses were so scattered from condition to condition, an analysis of variance of extraneous responses was not attempted. They have been categorized in Table IV, however, in terms of their frequency under the conditions of the main variables. With reference to the three conditions of spacing, they were divided as follows: 41 in the 6-sec. spacing group, 35 in the 30-sec. spacing group, and 25 in the 60-sec. spacing group. These differences, as tested by chi-square, are not significant. As for the degrees of learning variable, 68 extraneous responses oc-

TABLE IV

EXTRANEOUS ASSOCIATIONS AND FAILURES TO RESPOND AT RECALL

Variable and Condition	Frequency	$\frac{(f_o - f_t)^2}{f_t}$	Chi-Square and P
Degrees of learning:			105.3762
50 percent	68	72.3787	($P<.01$)
75 percent	23	0.2005	
100 percent	3	19.6064	
200 percent	7	13.1906	
Intervals following learning:			19.9109
0 min.	28	0.2995	($P<.01$)
2 min.	12	6.9530	
5 min.	19	1.5470	
20 min.	42	11.1114	
Conditions of spacing:			4.3601
6 sec.	41	1.6004	($.10<P<.20$)
30 sec.	35	0.5318	
60 sec.	25	2.2279	

curred in the 50-percent criterion group, 23 in the 75-percent criterion group, and 3 and 7 in the 100- and 200-percent criteria groups, respectively. This progressive decrease is significant at the .01 level by a chi-square test. As a function of the four intervals following learning, there were 28 in the no-delay category, 12 in the 2-min., 19 in the 5-min., and 42 in the 20-min. delay groups, respectively. A chi-square test showed these differences also to be significant at the .01 level.

It would appear that, as learning progresses, we may expect fewer extraneous responses at recall. What the implication is with reference to intervals following learning is not entirely clear, since the frequencies show a high level with no delay, then a drop followed by an increase with longer delays. Combining extraneous responses with remote associations over the various conditions, effects no change in the significances of mean differences in remote associations from that which has been presented.

DISCUSSION

Remote associations and degree of learning.—In discussing the relationship between remote associations and increasing degrees of learning, we should first point out that remote associations were present at recall following all of the four degrees of learning employed. We have found a somewhat lower percentage of remote associations, with reference to the total number of associations at recall, than has been reported with comparable methods and material (**16**, **20**). Our slightly different recall instructions may well be sufficient to account for the difference.

As the degree of learning progresses from a low degree of mastery of the list to a high degree of mastery, the frequency of remote associations is consistently reduced. The significant reduction comes when learning has progressed to between the 75-percent and the 100-percent level of mastery. Remote associations were not completely eradicated, however, even at the highest degree of learning. When learning had progressed to a point of two successively correct anticipations of the list, remote associations still constituted, on the average, three out of sixteen responses.

The reduction in remote associations with increased learning con-

firms the inferential findings, with the method of derived lists, of Ebbinghaus (2) and of Lepley (13). It also confirms the results of Hertzman and Neff (6), who used a group association method, under less well-controlled conditions with reference to the degrees of learning employed.

It is plausible to suppose that part of the rote learning process consists in the suppression of remote associations as forward adjacent associations become better fixated.

Remote associations and the interval following learning.—With regard to the relationship between remote associations and the interval following learning variable, we have shown that delays up to 20 min. do not differentially affect the frequency of remote associations at recall. Remote associations account for approximately one-third of the associations elicited at recall following each of the four intervals, 0, 2, 5, and 20 min.

These findings are at variance with results reported by Lepley (13), who found no evidence for the functioning of remote associations within derived lists, learned sooner than 30 min. following original learning. They do, however, support Hall's results (5), which report some saving in derived lists learned immediately following original learning. The present data also confirm previous studies using the association method (15, 20, 21), which report remote associations present after short delays following original learning.

The demonstration of remote associations after intervals up to 20 min. following learning has theoretical implications with reference to the Lepley theory of remote associations (10, 13). This theory states that remote associations are of the nature of trace and delayed conditioned responses. Such being the case, it is predicted that remote associations will be non-functional as prompt responses immediately or shortly following learning. The present data, based upon a direct measure of remote associations, are contradictory to Lepley's prediction, and evidence against his theory.

The data relative to the interval following learning also bear directly upon McGeoch's hypothesis to account for reminiscence, i.e., more rapid forgetting of remote associations as compared with adjacent associations. If remote associations so function, we would expect that the longer delays should reduce the number of remote associations. Since reminiscence has been reported after delays of two min. (7), and if the reminscence results from a dissipation of remote associations, we should certainly expect a reduction in their frequency after the 2-min. interval. No reduction was found after any interval. It should be pointed out that most reminiscence studies have used nonsense material; when adjectives have been used, the reminiscence effect is obscure (17). The failure to find a change in remote associations is therefore consonant with the failure to find reminiscence with adjective lists.

Remote associations and conditions of spacing.—We have shown that three degrees of spacing, 6 sec., 30 sec., and 60 sec. between trials, do not differentially affect the frequency of remote associations at recall. There is no literature on this variable which involves either the association method or the method of derived lists for measuring remote associations. Patten's results (18), which report anticipatory errors made under massed and spaced practice, are in agreement in one respect. Anticipatory errors during learning in Patten's study were not

significantly different under the two conditions of practice. However, when the lists were recalled and relearned after a 10-min. rest, Patten found more anticipatory errors within the lists learned by massed practice.

In the present experiment, the conditions of spacing served as another test of McGeoch's hypothesis, in that massed practice supposedly results in the persistence of remote associations, as compared with spaced practice. On this basis, we should expect more remote associations at recall, when learning was under the 6-sec. spacing condition than when it was under the wider forms of spacing. Since this has been shown not to be the case, the data must be considered as evidence against the McGeoch hypothesis.

Summary

The problem was that of the formation and retention of remote associations during rote learning. Three experimental variables were employed: (a) degree of learning; (b) massed *vs.* spaced practice; and (c) length of interval between the attainment of a specified criterion and a recall test. The degrees of learning were 50, 75, 100, and 200 percent perfect anticipation of the list. Three conditions of spacing were used: 6 sec., 30 sec., and 60 sec. between trials. Four intervals between learning and recall were employed: 0, 2, 5, and 20 min. of delay.

The purpose of the experiment was to gather systematic information concerning the formation of remote associations during rote learning, and to test McGeoch's hypothesis that remote associations dissipate at a more rapid rate than do adjacent or correct associations. The basic method for measuring remote associations was the *association method*, with 16-item adjective lists being learned serially on a Missouri-type memory drum, using a 2-sec. exposure rate.

The results indicate that remote associations consist of approximately 30 percent of all the associations made at recall under the conditions of this experiment. As the degree of learning in the lists proceeded from a low degree of mastery (50 per cent) to a high degree of mastery (200 percent), the number of remote associations was consistently reduced. The highest degree of learning did not, however, completely eliminate remote associations, but it did reduce them to an average of 3 out of 16 responses at recall.

The three conditions of spacing and the four intervals following learning were ineffective so far as differentially affecting the frequencies of remote associations was concerned.

The results are not favorable either toward the Lepley theory of remote associations or toward the McGeoch hypothesis of differential forgetting of remote as compared with correct associations.

(Manuscript received January 10, 1949)

References

1. Bugelski, B. R. The influence of the remote association gradient in determining the relative difficulty of items in serial rote learning. (Abstract) *Amer. Psychologist*, 1948, 7, 251.
2. Ebbinghaus, H. *Memory: a contribution to experimental psychology.* (Trans. by H. A. Ruger and C. E. Bussenius.) New York: Teachers College, Columbia Univ., 1913.
3. Fisher, R. A., & Yates, F. *Statistical tables for biological, agricultural, and medical research.* London: Oliver and Boyd, 1938.
4. Haagen, C. H. Scaling the principal attributes of words to be used in experiments in verbal learning. M.A. thesis, Univ. Iowa Library, 1942.
5. Hall, M. E. Remote associative tendencies in serial learning. *J. exp. Psychol.*, 1928, 11, 65–76.

6. Hertzman, M., & Neff, W. S. The development of intra-serial relationships in rote learning. *J. exp. Psychol.*, 1939, **25**, 389–401.
7. Hovland, C. I. Experimental studies in rote learning theory. I. Reminiscence following learning by massed and by distributed practice. *J. exp. Psychol.*, 1938, **22**, 201–224.
8. Hovland, C. I. Experimental studies in rote learning theory. II. Reminiscence with varying speed of syllable presentation. *J. exp. Psychol.*, 1938, **22**, 338–353.
9. Hovland, C. I. Experimental studies in rote learning theory. III. Distribution of practice with varying speeds of syllable presentation. *J. exp. Psychol.*, 1938, **23**, 172–190.
10. Hull, C. L. The conflicting psychologies of learning—a way out. *Psychol. Rev.*, 1935, **42**, 491–516.
11. Lashley, K. S. A causal factor in the relation of the distribution of practice to the rate of learning. *J. anim. Behav.*, 1917, **7**, 139–142.
12. Lashley, K. S. A simple maze: with data on the relation of the distribution of practice to the rate of learning. *Psychobiol.*, 1918, **1**, 353–367.
13. Lepley, W. M. Serial reactions considered as conditioned reactions. *Psychol. Monogr.*, 1934, **46**, No. 205.
14. Lorge, I. Influence of regularly interpolated time intervals upon subsequent learning. *Teach. Coll. Contrib. Educ.*, 1930, No. 438.
15. McGeoch, J. A. The direction and extent of intra-serial associations at recall. *Amer. J. Psychol.*, 1936, **48**, 221–245.
16. McGeoch, J. A. *The psychology of human learning: an introduction.* New York: Longmans, Green, 1942.
17. Melton, A. W., & Stone, G. R. The retention of serial lists of adjectives over short time-intervals with varying rates of presentation. *J. exp. Psychol.*, 1942, **30**, 295–310.
18. Patten, E. F. The influence of distributions of repetitions on certain rote learning phenomena. *J. Psychol.*, 1938, **5**, 359–374.
19. Ward, L. B. Reminiscence and rote learning. *Psychol. Monogr.*, 1937, **49**, No. 4.
20. Wilson, J. T. Remote associations as a function of the length of interval between learning and recall. *J. exp. Psychol.*, 1943, **33**, 40–48.
21. Wohlgemuth, A. On memory and the direction of associations. *Brit. J. Psychol.*, 1913, **5**, 447–465.

THE PERCEPTION OF THE VERTICAL: III. THE VISUAL VERTICAL AS A FUNCTION OF CENTRIFUGAL AND GRAVITATIONAL FORCES [1]

BY CLYDE E. NOBLE *

Tulane University and School of Aviation Medicine and Research, Naval Air Station, Pensacola, Florida

Introduction

Since 1700, when an obscure European toymaker constructed the first merry-go-round or carrousel (33), man has been subject to a unique visuo-equilibrial experience; i.e., the apparent tilting of the environment during uniform curvilinear motion. Similar phenomena are reported by individuals riding in motordromes (12), around railway curves (19), and in aircraft during coordinated turns (10, 27). From an historical point of view one might term this experience the merry-go-round phenomenon.[2] However, such a designation belies its profound significance for modern life, and for aviation in particular. Aeronautical research in two global wars has clearly emphasized the importance of visual and equilibrial perception in relation to flying.

The physical correlates of the psychological vertical may adequately be studied by means of a human centrifuge, which permits systematic isolation, variation, and repetition of the force variables in the absence of a visual framework. It is the purpose of this paper to describe a series of experiments designed to establish the quantitative relationship obtaining between the resultant of centrifugal and gravitational forces and the judgment of visual verticality in humans deprived of a visual frame of reference.

The notion that there may be physical determinants of phenomenal verticality seems to have been enunciated toward the close of the eighteenth century. Erasmus Darwin described the sensations of vertigo in 1794 (4), and in 1810 Wollaston accounted for seasickness in terms of blood pressure changes and the physical principle of inertia (19). In 1820 Purkinje (23) became the first to publish scientific observations of the now familiar merry-go-round phenomenon, and to suggest a few years later (24, 25) that spatial disorientation and vertigo following uniform rotation might be correlated with the effects of centrifugal force upon the brain and cardiovascular system of the body. According to Boring, he also "established the method of rotation" (4, p. 536). It was not until 1873, however, that Mach (17) attacked the problem systematically by designing a large 'rotation frame' in which he sat blindfolded and had himself propelled uniformly in a horizontal plane at a distance of two meters from the center of rotation (18, 19). Mach's experiments encouraged him to formulate an hypothesis; *viz.*, that when an individual is subjected to the resultant of centrifugal and gravitational forces "one senses the direction of the resultant

[1] This report is part of a series of investigations designated Project NR140-455 under Contract N7onr-434 Task Order I between the Office of Naval Research and The Tulane University of Louisiana in co-operation with the Bureau of Medicine and Surgery. (Task Order Director: Cecil W. Mann.) The experimental work was carried on at the School of Aviation Medicine and Research. The author is indebted to Capt. Ashton Graybiel (MC) USN, Dr. R. H. Brown, Dr. C. W. Mann, Dr. B. Clark, and Mr. F. E. Guedry, Jr. for helpful advice and assistance. Special apparatus was installed by Mr. J. R. Madsen.

* Now at the State University of Iowa.

[2] This has recently been called the 'oculogravic illusion' (10).

mass acceleration . . . and regards this as the vertical" (18, p. 27). Additional work involving an enclosed 'paper car' attached to the frame convinced Mach that when a plumb bob was suspended inside the car the visual vertical (V_v) was usually aligned with the angle of resultant force (ϕ), but not invariably. He wrote: "It occasionally seemed to me as if the vertical was located between the direction of the pendulum and the axis of my own body" (18, p. 28). This was an important secondary observation, as will become evident later.

In 1892 Kreidl (16), and later Breuer and Kreidl (8), conducted the first quantitative studies of the phenomenon. Their data, summarized in Table I, led them to the conclusion that V_v was perceived under uniform velocity as approximately half that of ϕ. It appeared to be a compromise judgment, and they attributed this apparent tilting of the visual field to "a real, unconscious counter-rolling of the eyes" (8, p. 499). Their assertion that visual localization was closely associated with eye movements and with the receptors of the non-auditory labyrinth was subsequently challenged by Cattell (9), Bourdon (5, 6, 7), Garten (11), and Tschermak and Schubert (26). The evidence pertaining to the nature and locus of the receptors for equilibrial sensitivity is controversial. Limitations of space do not permit a discussion here, but it is important to note that by 1920 the empirical findings argued against the doctrine of specificity (4). Gibson and Mowrer (12) have reviewed much of the literature dealing with the perception of the vertical and horizontal. They proposed the hypothesis that "*both the visual and the postural vertical are determined by visual factors and gravitational factors acting jointly, with orientation to gravity, however, as the more decisive factor in cases of real conflict between the two types of sensory data, and the primary factor genetically*" (12, p. 303).

Human judgment of the visual and postural vertical is very accurate, and the two modes of determination yield comparable results. Garten (11) had *S*s adjust a tilt chair to an upright posi-

TABLE I

Summary of Previous Determinations of the Visual Vertical (V_v) in Degrees as a Function of the Angle of Resultant Force (ϕ)

Investigator*	ϕ	V_v	Range	N
Mach	−10.0 to −20.0	$\approx\phi$	—	1
Kreidl **	(normals) −14.5	− 8.7	2.0 to −17.0	67
	(deaf-mutes) −14.5	− 6.0	2.7 to −15.0	62
Breuer & Kreidl	−14.0	− 7.8	− 7.0 to − 8.5	3
Bourdon	− 8.58	− 6.0	—	1
	− 9.03	− 6.4	—	1
	− 9.48	− 6.7	—	1
	−10.03	− 7.0	—	1
Witkin	light −25.0	− 3.3	0.0 to −11.0	30
	light −33.0	− 6.1	− 1.0 to −17.0	32
	dark −25.0	−10.8	− 3.0 to −35.0	30
	dark −33.0	−25.5	−15.0 to −37.0	27

* None of these investigators exhibited measures of variability.

** Kreidl's paper abounds in arithmetic errors and bizarre manipulation of data. Nineteen incorrect averages were discovered in two of his tables; individual CE's were based on a fluctuating N ranging from 1 to 17; data for four normal *S*s rotated at different speeds were included indiscriminately with those obtained under the standard conditions; and he arbitrarily rejected the data for one deaf-mute. The present author has therefore recomputed the above statistics from Kreidl's original data given in (16).

tion while blindfolded and found that their crude average error (AE) was less than 1.0°. Mann, Berry and Dauterive (20) recently completed a similar experiment, deriving a mean constant error ($\overline{CE}$) of 0.8°. They also computed variability data for both 'hard' and 'soft' conditions of the tilt chair. The group standard deviations (σ) were 1.9° and 3.4° respectively, and a *t*-test indicated that this difference was significant, with $P<0.01$. This evidence is in support of the theory of somesthesis as the primary basis of postural orientation. Neal (22) found her *S*s were able to adjust a luminous line in the dark with a mean average deviation ($\overline{AD}$) from the gravitational vertical (V_g) of 0.94°. This demonstrated that judgment of V_v depended upon V_g and not upon any visual framework. Nor could it be attributed to "the conservation of such a frame of reference after its perception has been abolished by the dark" (22, p. 291). Statistical analysis revealed no significant increase in the variable errors with continuing time in darkness. Other authors have agreed that acuity for V_v in a lighted environment is likewise a "seemingly self-contained function" (12, p. 312). These results are at variance with the 'spatial framework' hypothesis of Koffka (15), as well as recent elaborations by Asch and Witkin (1, 2, 31, 32), that the main lines of physical space determine the vertical and horizontal axes of visual experience.

By 1906 Bourdon had accepted Mach's primary hypothesis as a general law: "It is natural to assume," he wrote, "that we shall take (the) resultant for the vertical" (6, p. 84). But as a matter of fact, Bourdon's experimental results using an Aubert 'turning-table' did not establish the validity of the classical viewpoint. Examination of his raw data (*cf.* Table I) reveals that, as his own *S*, he consistently set a luminous line at an angle less than ϕ. One can only assume that Bourdon regarded the obvious discrepancies as chance or insignificant deviations from the resultant angle, for he was aware of the contrary findings of Mach, Breuer, and Breuer and Kreidl. In 1946 Graybiel, Hupp, and Patterson (14) restated essentially the same hypothesis, implying a causal relationship between the phenomenon and direct stimulation of the otoliths of the utricular maculae.

The most recent quantitative study of the merry-go-round phenomenon was reported by Witkin (28) in 1944. His *S*s were enclosed in a car and subjected to rotary motion as in Mach's original procedure. Both light and dark conditions were provided, and *S* was required to make three adjustments to verticality and horizontality in each situation and under two different velocities of rotation. The results appear in Table I and indicate differential responses in the two situations. Witkin concluded that "*displacing the gravitational vertical* by as much as 33° through the introduction of a laterally acting centrifugal force, typically failed to produce any *significant* change in the direction of the perceived upright, when an upright visual field was available" (28, p. 37).[3] However, there are certain objections to accepting these conclusions at face value: (1) He termed his *S*s' adjustments 'average deviations,' but they are evidently mean constant errors. (2) Specific subject instructions were not cited, making it impossible to evaluate his criteria of the visual vertical and horizontal. (3) Finally, no variability statistics were exhibited, nor was there any analysis of the significance of the observed differences. In subsequent studies (29, 30) Witkin had *S*s adjust their postural positions under varying rotary speeds, but again he did not report dispersion data.

Definitions

Visual vertical (V_v): a motor adjustment based on *S*'s judgment of apparent verticality relative to the horizontal plane of the floor of the centrifuge, measured as the angle made by an adjustable luminous collimated line with the gravitational

[3] Italics are those of the writer.

vertical in darkness under stationary or rotary conditions.

Gravitational vertical (V_g): the zero adjustment of the collimated line, empirically determined as the $\overline{CE}$ of three *S*s' 20 individual equations of the variable to a standard stimulus consisting of a plumb line suspended in front of the collimator under stationary conditions.

Angle of resultant force (ϕ): the angle described with the terrestrial vertical by the synchronous repeater indicator (phimeter) in the control tower, determined by the displacement of a pendulum mounted on a pivot point on the blackout car at a distance of 20 feet from the center of rotation of the superstructure.

Procedure

Apparatus.—The equipment consisted of an engine-powered, air-brake-controlled human centrifuge with a 2.5 × 3.8 × 6.4 feet blackout car of metal, wood, and canvas construction mounted rigidly at a distance of 20 feet from the center of rotation. Viewed from the control tower, the superstructure rotated in a counterclockwise direction with *S* facing the forward end of the car. A Navy Collimated Star, Mark II, was modified as a dual-control, electrically-driven collimator yielding a luminous line emanating from a source of apparent infinity. This was installed in the car within convenient reach of *S* and provided with a reversing position control geared to a selsyn transmitter. A modified repeater-type altimeter was wired into the circuit, calibrated in degrees, and served as a recording device for *S*'s settings of V_g and V_v. The offsetting of the visual stimulus was controllable both from the tower and from the car. The calibration and zero adjustment of this apparatus was checked daily. It was possible to read the altimeter to within 0.04°. Another circuit included a set of synchronous repeater motors, the transmitter of which was geared to a weighted pendulum at the rear of *S*'s car. Its receiver in the tower was equipped with a pointer moving over a large protractor dial graduated in quarters of a degree. Weston tachometers indicated the rotary velocity of the superstructure in r.p.m., and an Esterline-Angus recording tachometer furnished a permanent graphic record of acceleration, deceleration, and quarter-revolution data. Two-way communication was established between the glass-enclosed observation tower and the blackout car, a throat microphone being installed for *S*'s convenience. The car was equipped also with a bite-board, headrest, cockpit seat, and body straps to maintain *S*'s immobility. All controls were centrally located in the tower and mounted in separate panels for the centrifuge operator and for *E*.

Method.—*S*s used in the experiment were three male psychologists. All had prior knowledge of the general object of the investigation and were experienced observers. Before the experiment began they were instructed as follows:

> This is an experiment on visual perception in relation to centrifugal and gravitational forces. You will be seated in a human centrifuge under blackout conditions and subjected to varying speeds of rotation. During this time a luminous line will be exposed and tilted at different angles. Your task will consist of adjusting it a number of times so that it appears perfectly vertical; i.e., *perpendicular to the floor of the centrifuge.* The exact procedure of making determinations will be made clearer to you following further instructions.

S was then seated in the blackout car in such a manner that he was sighting into the collimator at the luminous line, with his teeth firmly grasping the bite-board provided, so that the medial plane of his head approximated the terrestrial vertical. This was achieved by adjusting the bite-board before each series with a carpenter's level, and by means of a headrest which supported the right temporal area and kept *S*'s head fixed during rotation. His body was secured in place in the cockpit seat with regulation aviation chest and waist straps. After *S* had donned the headphones and throat microphone, the elimination of external visual stimuli was insured by the additional precaution of a black cloth hood placed over him. All *S*s were seated so that the center of the head was at the same distance from the center of rotation of the centrifuge superstructure. With *S* enclosed in the stationary blackout car in the manner described, *E* proceeded to vary the visual stimulus by offsetting the luminous line in the vertical plane between 0.0° and 30.0° in either direction from V_g. Ten such offsets were made per trial, alternating the direction in the prearranged order: RLLR RLLR RL. This counterbalanced order was introduced to control constant errors of movement. *S* was required to adjust the line each time so that it corresponded with his criterion of V_v.

S was restricted neither in the time required to make an adjustment nor in the manner of equating the variable stimulus with V_v, in conformity with the psychophysical method of average error. All adjustments, however, were made consecutively and without unnecessary delay in order to avoid fatigue and adaptation effects.

After completing daily initial determinations in a stationary position, *S* then continued to make similar adjustments under conditions of varying resultant force. This was accomplished by varying the rotary velocity of the centrifuge between 4 r.p.m. and 11 r.p.m. by intervals of one r.p.m. in one ascending and one descending series of eight sittings each, so that every prearranged magnitude of resultant force occurred twice in the entire experiment for all *S*s. Ten adjustments in a stationary position were made before each run as a control test. The entire sequence therefore involved a total of 32 trials for each *S* and explored the physical magnitudes cited in Table II. The empirical values of ϕ were read directly on the phimeter and agreed closely with the values computed from velocity data using the principle of vectors. A further check on the uniformity of individual speeds was provided by the Esterline-Angus tachometer record.

Following his completion of 10 equations during rotation, *S* was directed to leave the car for a rest period. The next *S* was then introduced to the experimental situation, and so on throughout the study. No *S* was subjected to more than two runs per day, and the time elapsing between daily runs was never less than one-half hour.

The operator of the centrifuge accelerated the superstructure to a given velocity by a constant rate so that there was approximately a uniform acceleration for all *S*s. The total time required for individual runs varied between six and nine min., depending upon the magnitude of the velocity to be reached. *S* was directed each time to close his eyes at the onset of rotation; then, shortly before being signalled to open his eyes, he was reminded of the criterion of V_v. This precaution served to maintain a comparable set for each individual, as well as to avoid the Gibson-Radner effect (13). Determinations were not begun until 15 sec. after the desired rotary velocity had been reached, in order to control the effects of angular acceleration. The total series consumed a period of eight days, and all trials took place between the hours of 8:00 and 11:30 A.M. Temperature and humidity were controlled by means of an air-conditioning system which regulated the room temperature within a range of 72° to 78°F. Auditory stimuli were considered negligible since both *E* and the operator were enclosed in a 'sound-resistant' control tower. Light conditions were controlled by means of the blackout arrangements so that the only stimuli in *S*'s visual field emanated from the light source in the collimator. This was set at a fixed supraliminal intensity for all *S*s, sufficiently low to avoid producing after-images.

TABLE II

CONSTANT AND VARIABLE ERRORS IN ADJUSTMENTS OF THE VISUAL VERTICAL IN DEGREES CORRELATED WITH VARYING EMPIRICAL MAGNITUDES OF ϕ FOR THREE *S*s (N = 10 AT EACH VELOCITY)

RPM	ϕ	RHB		FEG		CEN	
		CE	σ	CE	σ	CE	σ
4	− 6.2	− 5.84	1.06	− 5.84	0.53	− 7.07	0.60
5	− 9.7	− 7.32	1.69	− 9.06	1.15	− 9.70	0.93
6	−13.8	− 9.95	1.65	−13.45	0.42	−11.60	1.15
7	−18.5	−11.24	1.65	−21.36	1.36	−16.75	0.81
8	−23.6	−17.32	1.44	−25.15	1.19	−18.80	2.67
9	−28.9	−23.21	2.33	−36.13	1.52	−26.68	1.10
10	−34.3	−26.60	2.88	−47.40	1.65	−31.70	1.14
11	−39.5	−34.85	3.05	−50.61	1.40	−39.56	0.83
11	−39.5	−37.74	1.52	−58.57	1.31	−36.21	0.64
10	−34.3	−35.71	2.25	−55.86	2.50	−29.61	0.87
9	−28.9	−29.18	2.79	−47.50	1.12	−27.78	0.84
8	−23.6	−24.69	1.38	−37.88	1.14	−20.79	0.91
7	−18.5	−17.47	1.10	−24.01	1.82	−18.63	0.44
6	−13.8	−14.32	0.72	−17.24	1.48	−14.91	0.68
5	− 9.7	− 8.89	0.91	−10.84	1.10	−10.29	0.40
4	− 6.2	− 7.11	0.85	− 5.80	0.91	− 7.67	0.29

Results

The treatment of the data appears in Table II and Fig. 1 for individual *Ss*, and in Fig. 2 for their performance as a group. Fig. 2 shows V_v as a function of ϕ. Each point on the graph represents the mean of three means of 20 adjustments each, a total of 60 observations. Since V_v was defined relative to V_g, the latter occurs as the zero point on the axis of ordinates. The composite stationary V_v was defined as the $\overline{CE}$ of 480 adjustments. Individual V_v's were characterized by slight inter- and intra-individual differences, with respect to both constant and variable errors, and these have been omitted from Table II in the interest of brevity. However, in Fig. 1 these stationary $\overline{CE}$'s are plotted opposite the zero value on the ordinate for each *S*. It may also be mentioned that V_v's obtained under conditions of rotation have not been 'corrected' for the constant errors noted during the preceding stationary situations. The linear plot represents the function predicted from Mach's hypothesis.

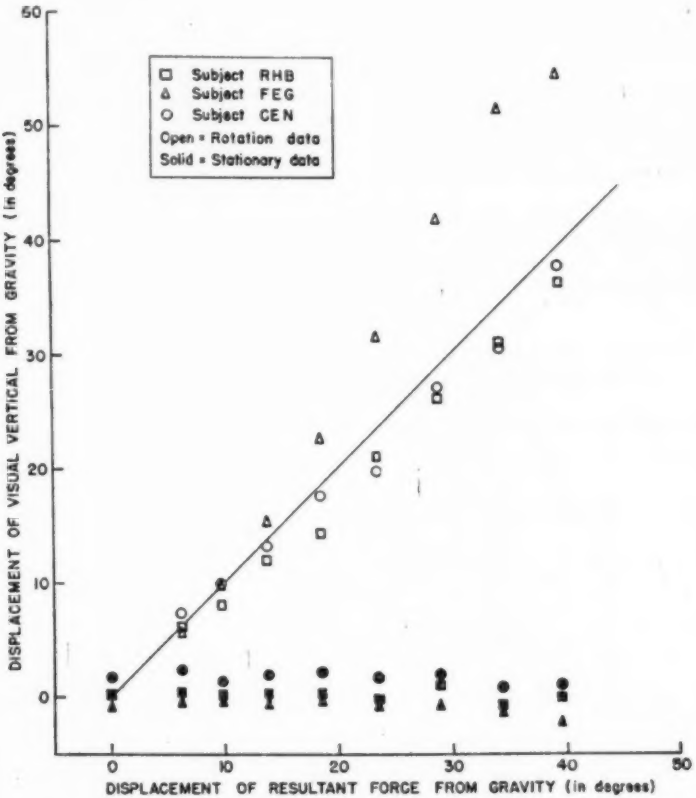


Fig. 1. The relation between the angle of resultant force (ϕ) and the visual vertical ($\mathcal{V}_v$) in the absence of a visual framework (individual data)

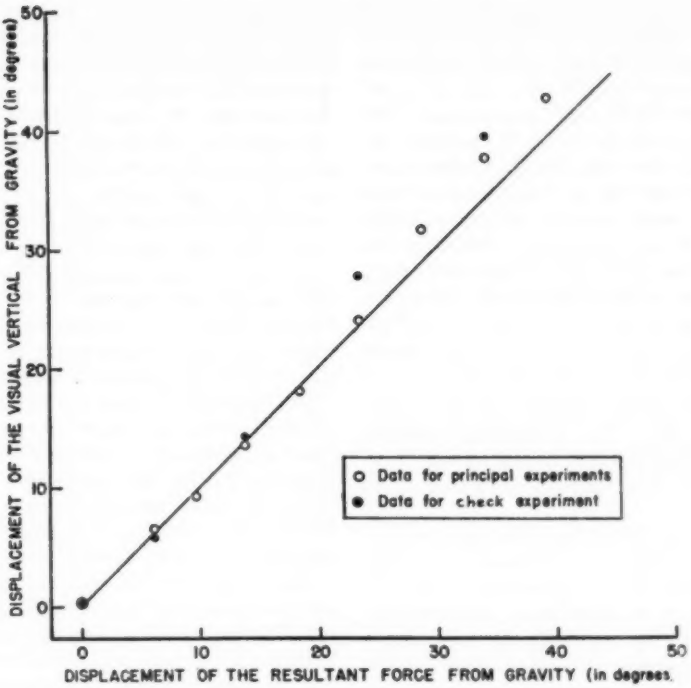


FIG. 2. The relation between the angle of resultant force (ϕ) and the visual vertical (V_v) in the absence of a visual framework (combined data)

TABLE III

CONSTANT ERRORS IN ADJUSTMENTS OF THE VISUAL VERTICAL (V_v) IN DEGREES DURING CONTINUOUS EXPOSURE TO ROTATION IN TWO SERIES IN THE CHECK EXPERIMENT FOR THREE *Ss* ($N = 5$ AT EACH VELOCITY)

RPM	ϕ	RHB CE	FEG CE	CEN CE
0	0.0	0.77	0.76	− 0.97
4	− 6.2	− 4.92	− 5.40	− 7.68
6	−13.8	−14.57	−16.50	−13.60
8	−23.5	−26.60	−37.67	−22.51
10	−34.3	−39.06	−55.76	−33.52
0	0.0	− 0.34	0.93	− 2.70
0	0.0	0.34	1.55	− 1.48
10	−34.3	−30.45	−47.31	−31.25
8	−23.5	−21.18	−37.95	−21.85
6	−13.8	−11.86	−16.90	−13.02
4	− 6.2	− 5.80	− 5.42	− 6.35
0	0.0	1.06	0.42	− 2.75

Table III displays the CE's for each *S*'s adjustments of V_v during a terminal check experiment which will be described in the discussion. For comparison purposes, their $\overline{CE}$'s are also plotted on the graph in Fig. 2 as points representing means of the combined data for all *Ss*.

In all cases negative quantities denote adjustments to the left of V_g, i.e., in a counterclockwise direction.

DISCUSSION

The results of this investigation indicate that the empirical relationship obtaining between V_v and ϕ, in the absence of a visual framework, is a linear increasing function whose slope is 1.0. Individual variability

in settings of V_v ranged from a σ of 0.34° (FEG) to a σ of 1.15° (CEN) for stationary conditions, and from a σ of 0.29° (CEN) to a σ of 3.05° (RHB) for rotary conditions. The function of V_v and ϕ is therefore attended by considerable dispersion. In 36 out of 48 trials the variable errors were greater during rotation than in the stationary situation, but there was no evidence for a consistent increase in variability with increasing magnitude of ϕ. The individual $\overline{CE}$'s for the 10 stationary adjustments ranged from −2.67° (CEN) to 2.75° (FEG), with a group $\overline{CE}$ of −0.38° for all *S*s. The variability of these adjustments, also based on an *N* of 480, is indicated by a group σ of 1.30°.

The empirical function corroborates Mach's original hypothesis; *viz.*, that *S*s adjust V_v in accordance with the resultant of centrifugal and gravitational forces. This is the major finding of the present investigation. The variability data may be interpreted as quantitative support for his secondary observation; *viz.*, that intermediate adjustments are occasionally made. The fact of individual differences might account for Bourdon's results, while the discrepancies between the present findings and those of Kreidl, Breuer and Kreidl, and Witkin (*cf.* Table I) could be attributed in part to those investigators' inadequate control of set and adaptation.

It is believed that the apparatus used in the present experiments permitted greater accuracy of measurement than any used heretofore. The determinations of V_v in previous studies were hardly readable to less than 0.5°. In two cases (6, 28) *E* apparently recorded *S*'s adjustments of V_v from a car-mounted pointer-protractor device while the centrifuge was in rotation.

Comparison of variability data under stationary conditions with those of Neal (22) substantiates the findings she cited in connection with the hypothesis that V_v is primarily dependent upon V_g. By using the conversion factor of 1.2532 one may transform her $\overline{AD}$ of 0.94° into a σ of 1.18°, which is comparable with the group σ of 1.30° for stationary adjustments in the present experiments. This value also agrees well with that reported by Mann, Berry, and Dauterive (20) for determinations of the postural vertical in their non-padded situation.

An interesting trend in the data for individual *S*s was that the function was consistently displaced further from V_g during the descending series than in the ascending series (*cf.* Table II). When this effect first became apparent, it was considered to be correlated with possible changes in *S*'s criterion of V_v from day to day. Accordingly, a check experiment was instituted at the termination of the major investigation. This consisted simply of a brief continuous exploration of four magnitudes of ϕ (4, 6, 8, and 10 r.p.m.) in one ascending and one descending series of five adjustments at each level. Five stationary determinations were made both before and after rotation, yielding a total of 60 observations for the entire series. No delay period was allowed preceding individual adjustments; i.e., *S* was instructed to begin his settings as soon as uniform rotation was reached. Otherwise, the criteria and procedure were similar to those in the principal experiments. The time consumed for individual runs ranged from 8 to 10 min., and the two series were separated by a rest period of one-half hour. The results are presented in Table III and in Fig. 2. It is evident that under these conditions there was no consistent trend in the data associated

with ascending or descending explorations. Variability analysis was not undertaken in view of the small *N*'s involved, but the CE's agree favorably with each *S*'s previous adjustments of V_v shown in Table II. The physical and psychological correlates of the effect are not known, and it is recommended that a subsequent investigation be devoted to its study.

Another observation of possible theoretical importance pertains to the greater mean displacement of V_v from ϕ in the upper magnitudes, particularly those adjustments associated with ϕ values greater than $-23.6°$. The significance of the deviations of the last three empirical points from the expected values of V_v predicted from Mach's hypothesis (i.e., $V_v \approx \phi$) was determined by *t*-tests. (Using Lindquist's formula for the significance of the mean of a small sample, M_e was taken as the mean of the means for all *S*s, M_h was represented by ϕ, and $n = 6$.) The *t*'s corresponding to ϕ's of $-28.9°$, $-34.3°$, and $-39.5°$ are 0.80, 0.76, and 0.88 respectively. The differences are insignificant, with $P > 0.40$ in each case. One must conclude that statistical analysis does not warrant regarding these deviations as other than chance variations from the hypothetical function of V_v. However, since the probability of getting *t*'s as small as these depends upon the magnitudes of the deviations as well as upon the differences between the means, it is important to note that the extreme adjustments of one *S*, FEG (*cf.* Fig. 1), have operated to inflate the estimates of the standard error of the mean. Regarding the data for FEG separately, then, it is suggested that his trend may be analogous to the Aubert phenomenon, which is described (3) as a phenomenal tilt of a vertical luminous line, regarded in darkness, contrary to the direction of inclination of *S*'s head. Müller (21) amplified this observation and found that under conditions of lesser head inclination, the phenomenal vertical was reported to be displaced in the same direction. He termed the two effects the A- and E-phenomena, respectively. FEG's curve, suggestive of an ogive, indicates some evidence for the A-phenomenon since, in terms of Aubert's hypothesis, *S* is expected to make adjustments of V_v contrary to the direction of apparent tilt. Thus, during exposure to low rotary velocities the CE's would tend to diverge from ϕ in a counterclockwise direction. Evidence for the related E-phenomenon is lacking in view of the physical range investigated. The nature of the function beyond $-39.5°$ is, of course, a matter for future observation, not for present extrapolation. To have exceeded the limits of duration and magnitude of resultant force to which *S*s were exposed in these experiments was deemed inadvisable. Reports of discomfort were frequent above 8 r.p.m., and one *S* (FEG) complained of persistent sinus pains in the vicinity of 9 and 10 r.p.m.

In regard to the controversy over the relative dominance of visual and gravitational (postural) factors in spatial orientation, it is obvious that the results of these experiments offer no conclusive answer to that special problem.[4] Behavioral orientation is

[4] Asch and Witkin have concluded from their studies (1, 2) that "the main directions of the visual field play a decisive role in the perception of the vertical and horizontal" (31, p. 603). It should be pointed out that their experiments dealt only with determinations of the *visual* vertical and horizontal under conditions of varying visual and postural displacement. This is to say nothing of judgment of the *postural* axes under analogous conditions. The procedure of attenuating somesthetic sensitivity before ex-

a complex, integrated function consisting, in nonlaboratory situations, of all the participating sense modalities: vision, audition, the 'statokinetic' organs of the labyrinth, proprioceptive impulses from the skin, muscles, tendons, and joints—perhaps even the chemoreceptors. However, certain facts are clearly established. When a given sense department, e.g., the visual, is completely interdicted, *Ss* adapt themselves readily to other modalities and are able to localize the postural upright with marked accuracy. It is evident also that when visual data are so restricted as no longer to yield normal perception of the principal physical axes, individuals react in accordance with physical force variables when required to determine the visual vertical. According to Gestalt theory[5] the luminous line, regardless of its angular displacement, would have to be considered the fundamental determinant of the 'spatial framework' at that instant. But it must be emphasized that at no time in the present experiments did any *S* accept the structure of the visual field presented to him, during either stationary or rotary conditions. In every case—1140 times—there was an immediate adjustment of the luminous line to accord with *S*'s judgment of the phenomenal upright. Why then this discrepant behavior? The answer must lie in the experimental variables introduced via postural cues. It is apparent that, under these conditions, the latter are the primary determinants.

This is not to imply that ϕ, or even the magnitude of resultant force, is the sole causal agent in the perception of V_v in the absence of a visual frame of reference. It is evident, however, that a high degree of correlation obtains between them. The variability associated with this function prevents the concomitance from being perfect, and it is presumably attributable to such factors as the small number of *Ss* used, oscillation of the criterion of V_v, physiological impairment involved in fatigue, and the effects of adaptation.

posure to displaced visual fields seems not to have been tried. In the absence of other orienting stimuli, *Ss* would almost certainly react to the visual framework irrespective of its tilt. Such would be a companion experiment to the present investigation, neither of which, of course, can settle the dispute unequivocally. What is required ultimately is an experiment involving conflicting visual and postural cues which are of equivalent psychological magnitudes. But perhaps this poses a spurious problem in the statement of an infeasible requirement.

[5] In his discussion of perceptual organization, Koffka (15, p. 211 ff.) hypothesized that the framework is determined by the main directions of the visual field. He implied further (p. 216) that perception of both vertical *and* horizontal axes is necessary to satisfy the definition of the 'spatial framework.' This implication has been assumed in the present paper, i.e., that *Ss* were behaving in the *absence* of a visual framework. In a private communication, however, Professor Köhler indicates that he considers this a 'forced' interpretation. "My own tendency," he writes, "would be to adopt the hypothesis that the system vertical-horizontal is a unitary system, and that if either the vertical or the horizontal are established as facts of reference the other axis of space is *ipso facto* also determined as such a fact. Naturally, this hypothesis ought to, and can, be tested."[1] Thus, Köhler apparently considers the problem an empirical one rather than a matter of definition.

Summary and Conclusions

1. This research has been concerned with establishing the quantitative relationship obtaining between the resultant of centrifugal and gravitational forces and the judgment of visual verticality in three *Ss* deprived of a visual frame of reference in a human centrifuge.

2. The experimental procedure was as follows: *Ss* were placed individually in a human centrifuge and exposed to eight different velocities of rotation.

A luminous line was presented in darkness, and *S* was required to adjust it to phenomenal verticality a number of times under both stationary and rotary conditions, according to the psychophysical method of average error.

3. Statistical analysis of the data was made in terms of constant and variable errors.

4. The function investigated has been found to be a linear relationship; i.e., the visual vertical varies directly with the angle of resultant force.

5. There were individual differences in constant and variable errors during stationary conditions, but the combined data indicated that judgment of the visual vertical was both accurate ($\overline{CE} = -0.38°$) and precise ($\sigma = 1.30°$).

6. Intra-individual differences were greater during rotation than during stationary conditions.

7. These findings are interpreted as confirmation of Mach's hypothesis of the physical force determinants of psychological verticality. They are also consistent with the viewpoint that visual orientation, under the conditions of these experiments, is primarily dependent upon somesthetic factors rather than upon visual *Gestalten*.

(Manuscript received
November 22, 1948)

References

1. Asch, S. E., & Witkin, H. A. Studies in space orientation. I. Perception of the upright with displaced visual fields. *J. exp. Psychol.*, 1948, **38**, 325–337.
2. Asch, S. E., & Witkin, H. A. Studies in space orientation. II. Perception of the upright with displaced visual fields and with body tilted. *J. exp. Psychol.*, 1948, **38**, 455–477.
3. Aubert, H. Eine scheinbare bedeutende Drehung von Objekten bei Neigung des Kopfes nach rechts oder links. *Arch. path. Anat. Physiol.*, 1861, **20**, 381–383. N.S. 10.
4. Boring, E. G. *Sensation and perception in the history of experimental psychology*. New York: D. Appleton-Century, 1942.
5. Bourdon, B. La perception de la verticalité de la tête et du corps. *Rév. philos.*, 1904, **57**, 462–492.
6. Bourdon, B. Influence de la force centrifuge sur la perception de la verticale. *Année psychol.*, 1906, **12**, 84–94.
7. Bourdon, B. Sur le rôle de la tête dans la perception de l'espace. *Rév. philos.*, 1906, **61**, 526–529.
8. Breuer, J., & Kreidl, A. Über die scheinbare Drehung des Gesichtsfeldes während der Einwirkung einer Centrifugalkraft. *Pflüg. Arch. ges. Physiol.*, 1898, **70**, 494–507.
9. Cattell, J. McK. The sense of equilibrium. *Science*, 1895, **2**, 99–100.
10. Clark, B., Graybiel, A., & MacCorquodale, K. The illusory perception of movement caused by angular acceleration and by centrifugal force during flight. II. Visually perceived motion and displacement of a fixed target during turns. *J. exp. Psychol.*, 1948, **38**, 298–309.
11. Garten, S. Über die Grundlagen unserer Orientierung im Raum. *Abhandl. Math.-Phys. Klasse Sächs. Akad.*, 1920, **36**, 431–510. (n.v.)
12. Gibson, J. J., & Mowrer, O. H. Determinants of the perceived vertical and horizontal. *Psychol. Rev.*, 1938, **45**, 300–323.
13. Gibson, J. J., & Radner, M. Adaptation, after-effect, and contrast in the perception of tilted lines. I. Quantitative studies. *J. exp. Psychol.*, 1937, **20**, 453–467.
14. Graybiel, A., Hupp, D. I., & Patterson, J. L., Jr. The law of the otolith organs. *Fed. Proc. Amer. Soc. exp. Biol.*, 1946, **5**, 35.
15. Koffka, K. *Principles of Gestalt psychology*. New York: Harcourt-Brace, 1935.
16. Kreidl, A. Beiträge zur Physiologie des Ohrlabyrinths auf Grund von Versuchen an Taubstummen. *Pflüg. Arch. ges. Physiol.*, 1892, **51**, 119–150.
17. Mach, E. Physikalische Versuche über den Gleichgewichtssinn des Menschen. *Sitzungber. Math. Nat. Kl. Akad. Wiss. Wien, III Abt.*, 1873, **68**, 124–140.
18. Mach, E. *Grundlinien der Lehre von den Bewegungsemfindungen*. Leipzig: Wilhelm Engelmann, 1875, No. 4. (n.v.)
19. Mach. E. On sensations of orientation. In: McCormack, T. J. (Trans.), *Popular scientific lectures* (3rd Ed.), Chicago: Open Court, 1898, 282–308.

20. Mann, C. W., Berry, N. H. B., & Dauterive, H. J., Jr. The perception of the vertical. I. Visual and non-labyrinthine cues. *J. exp. Psychol.*, 1949, **39**, 538–547.
21. Müller, G. E. Über das Aubertsche Phänomen. *Z. Sinnesphysiol.*, 1916, **49**, No. 2, 109–244.
22. Neal, E. Visual localization of the vertical. *Amer. J. Psychol.*, 1926, **37**, 287–291.
23. Purkinje, J. E. Beiträge zur näherer Kenntniss des Schwindels aus heautognostischen Daten. *Med. Jb. Osterr. Staates. Wien*, 1820, **6**, 79–125.
24. Purkinje, J. E. Physiologische Versuche über den Schwindel. *Bul. naturwiss. Sect. schles. Ges. Breslau*, 1825, No. 10. (n.v.)
25. Purkinje, J. E. Über die physiologische Bedeutung des Schwindels. *Bul. naturwiss. Sect. schles. Ges. Breslau*, 1825, No. 12. (n.v.)
26. Tschermak, A., & Schubert, C. Über Vertikalorientierung im Rotatorium und im Flugzeuge. *Pflüg. Arch. ges. Physiol.*, 1931, **228**, 234–257.
27. Vinacke, W. E. Illusions experienced by aircraft pilots while flying. *J. aviat. Med.*, 1947, **18**, 308–325.
28. Witkin, H. A. *An investigation of problems of space orientation as related to the selection and training of pilots.* Brooklyn College, ONR Project N7onr323, Feb. 1944, 1–54.
29. Witkin, H. A. *Progress report No. 1.* Contract N7onr323, Aug. 1947, 1–50.
30. Witkin, H. A. *Progress report No. 3.* Contract N7onr323, Feb. 1948, 1–17.
31. Witkin, H. A., & Asch, S. E. Studies in space orientation. III. Perception of the upright in the absence of a visual field. *J. exp. Psychol.*, 1948, **38**, 603–614.
32. Witkin, H. A., & Asch, S. E. Studies in space orientation. IV. Further experiments on perception of the upright with displaced visual fields. *J. exp. Psychol.*, 1948, **38**, 762–782.
33. *Whence the merry-go-round?* (Anon.) *The Mentor*, 1928, **16**, No. 11, 64.

LEARNING FUNCTION FOR A CHANGE IN THE SCALE OF JUDGMENT

BY DONALD M. JOHNSON

Michigan State College

It is relatively easy to construct a learning curve for those aspects of behavior which show regular improvement with practice: which show, that is, regular increase in the frequency or speed of those responses which can be classified as correct. But learning theory should consider also the learning of responses that occur in abstract patterns, some of which cannot easily be labelled right or wrong. Curves for the acquisition of concepts have been published, it is true, but these curves show, not what the subject is learning, but rather how rapidly he is learning that pattern of responses which the experimenter considers correct. If we wish to know what the subject learns during practice, periodic testing with questions of the open-end variety, such as "What is a dax?", "Draw a thun," or "What do you mean by mammal?", are more informative, but it is hard to scale them in such a way that the development of the concept can be graphed.

In the case of the formation and change of attitudes the situation is more promising. With the aid of an attitude scale the subject's attitude can be described, in one dimension at least, with fair accuracy, and then practice or experience can be given and attitude tested again. The disadvantage is that, under conditions in which the kind and amount of practice can be controlled, it is difficult to obtain more than two or three points on the curve.

A frame of reference or scale of judgment[1] may be considered an abstract concept, a generalization based on many specific instances. The subjective scale used in judging pitch is one which can be described with reasonable precision, as to midpoint at least; hence it should be possible to plot the course of changes in the midpoint of the scale when controlled experience is introduced. Previous papers in this series (5, 6, 7) give a theoretical background for the patterning of a reference scale and the prediction of its midpoint; the present paper deals with the more interesting case in which the scale is experimentally shifted upward or downward.

Tresselt (9) has recently published some curves showing how a scale formed by practice in judging one series of weights shifts when another series is judged. The points are somewhat irregular and the shape of the curves cannot be precisely determined, so Tresselt compares the first points on each curve and reaches the conclusion that "the larger the period of practice the more slowly does the scale of judgment shift to its new position."

A Rational Equation

The previously outlined theory states that the category limen, the statistically determined threshold or

[1] The term 'scale of judgment' is preferred here because 'frame' seems to imply at least two dimensions. When the stimuli to be judged differ from one another in only one important respect, as in the present experiment, 'scale' is a more precise term. But there is no reason a priori why the principles developed herein could not be extended to the multidimensional, or frame-of-reference, experiment in which the judgments are determined by several kinds of variation among the stimulus objects.

transition point between the categories 'high' and 'low,' is an average of the stimulus values of the series from which the scale is formed. This average in the case of pitch is the geometric mean of the stimuli expressed in cycles per second. Helson (2) in a paper called *Adaptation-Level as Frame of Reference for Prediction of Psychophysical Data* uses a modified geometric mean suitably weighted to take account of the standard stimulus and the background, and finds that he can predict the results of a wide variety of psychophysical experiments. The theory is a general one which ought to fit the present conditions in which the series is shifted as well as the more common conditions in which the same series is used repeatedly.

We can begin, therefore, with the equation for the geometric mean,

$$\log L = \frac{\Sigma \log x_i}{N} \qquad (1)$$

in which L is the category limen or adaptation level, x_i represents the frequencies of all the sounds presented for judgment, and N is the total number of such sounds. If the values of x are raised or lowered to a new level and held there, as in the present experiment, L will rise or fall correspondingly in a negatively accelerated curve.

To rewrite this as a function of number of series or trials, as equations for learning curves are usually written, we can use the limens, L_1 and L_2, for the first and second series respectively, computed as above, and simply combine them in a weighted average.

$$L_n = \frac{wL_1 + nL_2}{w + n}. \qquad (2)$$

In this formulation n represents the number of times the second series of stimuli has been presented for judgment. L_2 is weighted by n, therefore, and L_1 is weighted by w, an empirical constant indicating the weight of the first or pre-shift series in impeding adaptation to the second or post-shift series. L_n is the category limen or adaptation level at the time of the nth practice trial, i.e., the nth presentation of the second series. The expression could be considered a moving average. It begins at L_1 and takes the form of a hyperbola with L_2 as an asymptote.

Equation 2 is altogether reasonable in theory. The chief problem is to arrange experimental conditions which meet the assumptions of the theory in order to get an empirical check. Fortunately, L_1 and L_2 can be calculated by Equation 1; hence there is only one constant, w, to be determined. This simplifies the task of verification considerably.

A Method of Group Psychophysics

The data of the preceding experiment (7) were obtained by having college students, working individually, judge the pitch of sounds produced by an audiometer. The procedure was fairly convenient and the obtained results agreed quite well with the predictions of Equation 1. In order to cut down the time required for gathering the data of the present experiment the procedure was adapted to group administration. The sounds, produced as before by a Western Electric 6B Audiometer, were led into a General Electric Magnetic Wire Recorder and then, suitably amplified, were played back to groups of subjects who indicated their judgments on an answer sheet.

The principal difficulty in making the recordings was the control of loudness. Several preliminary recordings were made and played back to small groups of subjects who judged each sound for loudness. Then repeated adjustments of both audiometer and recorder were made for each sound until a recording was obtained in which the stimuli were approximately equated for loudness to the average college student's ear.[1]

[1] Acknowledgment is due Albert Chalupsky and Fred Proff, assistants in psychology at the Duluth Branch of the University of Minnesota, for help with these recordings.

For the present experiment, which does not depend upon a perfect equation for loudness, this arrangement permitted the use of frequencies up to 5000 cycles per sec., and the ease of recording and erasing with the wire recorder is a distinct advantage if many recordings must be made and permanence is not necessary.

Spacing the sounds a quarter-octave apart makes available a range of 18 stimuli from 256 to about 4870 cycles per sec. These were numbered 1 to 18 for convenience in computation—permitting the use of the arithmetic rather than the geometric mean—and separated into two series of nine stimuli each, numbered 1 to 9 and 10 to 18. By Equation 1 the category limen for the low series would be 5, for the high series, 14.

Each stimulus was presented for 1.5 sec. with an interval of 5 sec. between stimuli. A series of nine stimuli required about a minute. In the recording each stimulus was preceded by a spoken number, and blanks on the answer sheet bore corresponding numbers. Order of presentation was random.

To each group of subjects the following instructions were read.

> This is an experiment in judging pitch. You will hear several series of sounds and you are to call each one 'high' or 'low.' If a sound seems high in pitch, write H in the blank for that number. If it sounds low, write L. At first you may be confused because you won't know what to call 'high' and 'low.' But you will get used to it as you go along.

All subjects cooperated well. No data were discarded.

Since our interest is in the general trend rather than individual differences, the judgments of all subjects of an experiment were combined and the group category limen or point of subjective equality was computed for each series of nine stimuli by the constant-stimulus method.

The First Experiment

For the first experiment a descending shift was arranged. The sounds numbered 10 to 18, of frequencies 1220 to 4870, were used as the first series and the sounds numbered 1 to 9, of frequencies 256 to 1024, were used as the second series. A recording was made in which the first series was presented three times, then without break the second series was presented seven times. The subjects were 25 college students.

Even though the experiment required only 10 min. of actual judgment, the task is not particularly interesting and the possibility of boredom or change of attitude must be considered. Hence, the experiment was repeated with the same recording but another group of 23 subjects, and a rest of five min. was allowed in the middle of the experiment, that is, between Trials 2 and 3 of the second series. But the data of the two groups were indistinguishable, so they are combined and the data for all 48 presented in Table I and Fig. 1. Henceforth there was no allowance for rest.

TABLE I

Midpoints, Calculated in Quarter-Octaves, of a Subjective Scale Used for Judgments of Pitch as the Scale Shifts to a Lower Level ($N = 48$)

	Trial	Midpoint
First series 10–18	1	13.0
	2	14.1
	3	14.4
Second series 1–9	1	7.1
	2	6.3
	3	5.4
	4	5.2
	5	5.1
	6	5.3
	7	4.8

If our theory is correct, the limen calculated from the judgments of each of the first three series will be 14. Then, after the shift in the stimuli presented for judgment, the limen will move toward 5, the predicted limen of the second series. The shift is described by Equation 2 in which L_1 is 14 and L_2 is 5 and the trials are numbered from the introduction of the second series. Fitting the obtained data with Equation 2 by the method of averages a value of 0.13 for w is obtained. From Fig. 1 it is

apparent that the theoretical curve agrees fairly well with the obtained data.

The first point for the pre-shift series is lower than the predicted value for L_1, but the first point could perhaps be neglected as a certain amount of preliminary adjustment would be expected. The second and third limens are close to the predicted value and the average of all three is 13.83 which is not far from the predicted value of 14. The shift beginning with the introduction of the second series must be a hyperbola, or something like one, and the asymptote must be in the neighborhood of 5. The results of the first experiment, then, give considerable support to the theory.

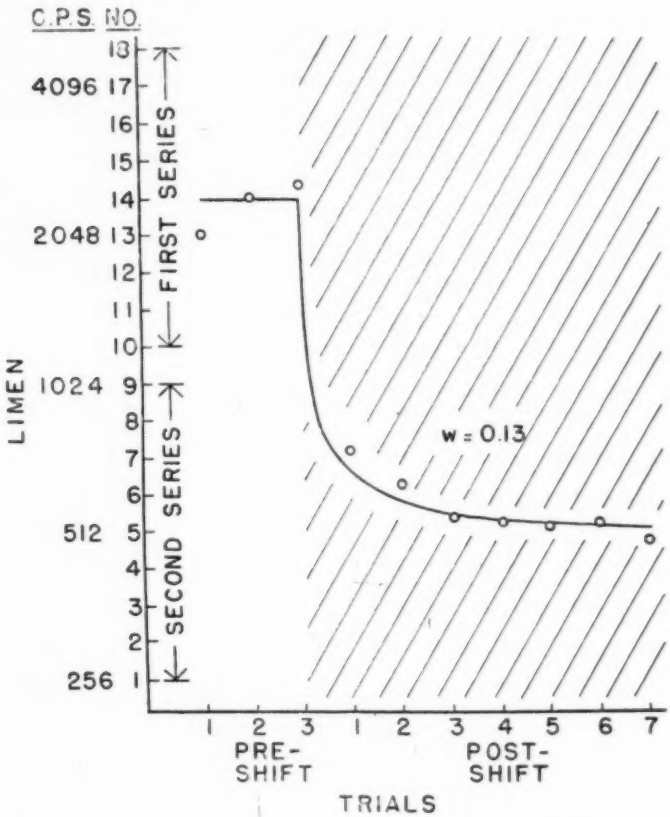
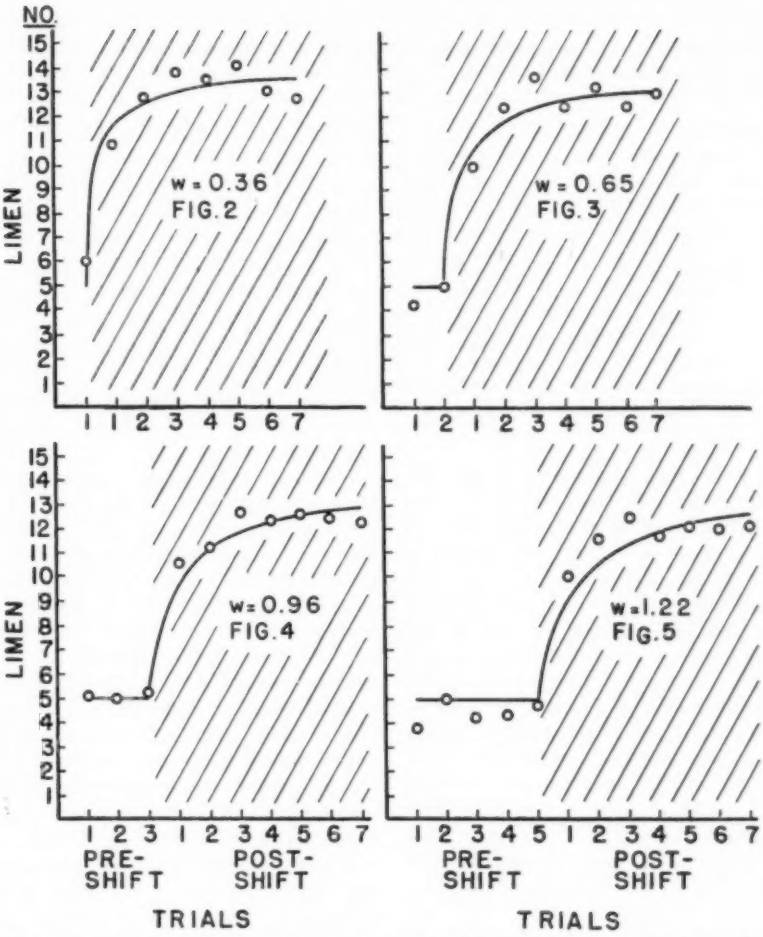


FIG. 1. Learning curve for the shift in a scale used in judging pitch. The ordinate may be read in cycles per sec. or in quarter-octaves. The circles represent group limens or midpoints of the subjective scale; above these points the sounds were, in general, judged 'high' and below them the sounds were judged 'low.' The theoretical curve locates the limen at 14 for the three trials with the first series, then it rapidly approaches 5 as an asymptote in the seven trials with the second series. The agreement of theory and fact may be judged by the deviations of the circles from the curve.



FIGS. 2–5. The effect of different amounts of practice with the first series on rate of adapting to the second series. The first series was presented 1, 2, 3, and 5 times and the second series was presented 7 times. The theoretical curve locates the limen for the first series at 5, and with the introduction of the second series it approaches 14 as an asymptote. The weight of the first series in retarding adaptation to the second is indicated by the empirical constant w. Comparing the four figures shows that the greater the amount of practice with the first series the slower is the shift to the level of the second.

THE SECOND EXPERIMENT

For the second experiment an ascending shift complementary to the descending shift of the first experiment was arranged. The sounds numbered 1 to 9 were used as the first series and those numbered 10 to 18 as the second series. Otherwise the procedure was identical. The subjects were 23 college students. The data are included in Table II and graphed in Fig. 4.

TABLE II

MIDPOINTS, CALCULATED IN QUARTER-OCTAVES, OF A SUBJECTIVE SCALE USED FOR JUDGMENTS OF PITCH AS THE SCALE SHIFTS TO A HIGHER LEVEL

	Trial	Midpoint	Trial	Midpoint	Trial	Midpoint	Trial	Midpoint
First series 1–9							1	3.8
							2	5.0
					1	5.2	3	4.2
			1	4.2	2	5.0	4	4.3
	1	6.0	2	5.0	3	5.3	5	4.7
Second series 10–18	1	10.8	1	10.0	1	10.6	1	10.0
	2	12.8	2	12.4	2	11.2	2	11.6
	3	13.9	3	13.8	3	12.7	3	12.4
	4	13.6	4	12.4	4	12.4	4	11.7
	5	14.2	5	13.2	5	12.6	5	12.1
	6	13.1	6	12.5	6	12.5	6	12.0
	7	12.8	7	13.0	7	12.3	7	12.1
	$N = 12$		$N = 8$		$N = 23$		$N = 19$	

It is apparent from Fig. 4 that the three limens for the first series are predicted quite well by Equation 1. The average of these three limens is 5.17, to be compared with the predicted value of 5. The shift upward with the introduction of the second series is about what one would expect but it is slower than the corresponding shift downward of Fig. 1. The curve of Equation 2 fit to these points seems to describe the data reasonably well in view of the irregularity. Calculated by the method of averages, w has the value of 0.96. It is not obvious why the value of w should be so much greater for the ascending than for the descending shift. On the whole the results of the first two experiments, in which two sets of data are described by the same equation, with only one constant to be computed for each, reinforce the theory.

THE THIRD EXPERIMENT

Assuming that Equation 2 fits the facts reasonably well, the next step is to determine the conditions that affect the constant w, representing the weight of the first series in inhibiting adaptation to the second. The amount of experience with the first series, as measured by the number of trials or judgments of this series, is obviously one independent variable to be considered. A set of experiments was arranged, therefore, in which the first series was presented one, two, and five times before the shift to the second series. The ascending shift seemed to allow more room for variation than the descending shift; hence this experiment repeated the second experiment as closely as possible except for the number of presentations of the first series.

One recording was made with several presentations of the low series followed by seven presentations of the high series. For one group of 12 subjects the play-back was cut in at one presentation of the first series. For another group of 8 subjects the record was cut in at two presentations of the first series. (From the second experiment we have the data of 23 subjects with three presentations of the first series.) For another group of 19 subjects the first series was presented five times. The results are included in Table II and graphed in Figs. 2, 3, and 5.

All of these plots show considerable irregularity. While some of the deviations from the theoretical curves are random, close study will suggest a pattern in the deviations. A similar phenomenon was pointed out by Tresselt (9) in her graphs; hence, although perhaps unimportant for present purposes, the discrepancies are probably not purely random.

In spite of these small discrepancies the hyperbola of Equation 2 as it stands fits the five sets of data fairly well. A strong argument in favor of Equation 2 is that it fits all five sets of data with the calculation of only one empirical constant, w. And for the four ascending shifts of Figs. 2 to 5 the variation in this constant is altogether rational. Its weight increases regularly in the expected manner as the number of exposures to the first series is increased.

This constant, w, then, is influenced by the number of presentations of the pre-shift series, by the conditions of the shift—since the ascending shift is slower than the descending shift—and presumably also by differences between the subjects. The individual difference involved here might be related to flexibility in other kinds of shifts, as in the concept-formation tests and tests of sensory perseveration. These three factors included in w could be investigated separately if necessary.

Equation 1, as well as Equation 2, is supported by these data. The midpoint of the low series, which is predicted as 5, was determined 11 times. The mean of these eleven values is 4.80, which agrees quite well with the prediction. As was mentioned earlier, the midpoint of the high series is predicted equally well.

Discussion

In none of these curves is the agreement of theory and fact as convincing as one might wish. We are working in a rather difficult area of psychology in which variations are produced by differences in the subjects' backgrounds, their understanding of the instructions, and, perhaps most important, by changes in attitude or set during the course of the experiment. Putting all experiments together, however, yields considerable support for the pre-experimental hypothesis: that the scale which functions at any time is a moving weighted average of the practice effects left by the experience from which the scale is formed.

The hypothesis should, of course, fit other data as well as the data of the present paper. Therefore an attempt was made by several methods of analysis to apply Equation 2 to Tresselt's (9) data mentioned earlier. The data of three of her groups, Groups II, III, and IV, are fairly regular, and for these Equation 2 fits quite well. The data of her other groups are not sufficiently regular to confirm or negate the theoretical curve.

The next question concerns the weight of the pre-shift practice trials in slowing down the shift to the level of the second series. In this respect the results of the present experiments are clear-cut. The constant w, indicating the weight, for the four ascending shifts, of one, two, three, and five pre-shift practice trials, takes the values respectively of 0.36, 0.65, 0.96, and 1.22. The constants calculated for Tresselt's three groups which had four, eight and twelve pre-shift practice trials, also varied in the expected way. For this kind of experiment, within these limits, then, the speed of the shift is inversely related to the number of practice trials with the pre-

shift series. This is analogous to the situation in conditioning experiments where the rate of extinction is, under some conditions, inversely related to the number of reinforcements.

An experiment somewhat similar in principle to the present experiments was reported briefly by Youtz (11). He had his subjects work problems which could be solved by one method, then, without explanation, they were given problems which could only be solved by a different method. Some subjects worked 5 problems by the first method, some worked 10, some 20, and some 40. The shift to the second method was impeded by practice with the first, and those subjects who had had the most practice with the first method mastered the second method most slowly. Apparently adaptation to a new method of solving problems is similar to adaptation to a new scale of judgment in respect to the effect of amount of pre-shift practice.

Another pertinent experiment was recently reported by Grant and Berg (1), with superficially contradictory results. They worked with a card-sorting task which was a modification of the Weigl-Goldstein-Vigotsky concept-formation test. Sorting on the basis of color was called 'right' at first, then without explanation number classifications were called 'right' and the others 'wrong.' In a similar way the basis of correct classification was shifted to form, back to number, then to color, and finally to form. Seven groups of subjects were used, one of which was allowed three correct trials with one classification before the shift to the next, another was allowed four, another five, and so on to ten confirming or reinforcing trials. It turned out that the groups with the larger numbers of pre-shift reinforcing trials made *fewer* errors, both perseverative and nonperseverative, after the shift. The chief effect of increased reinforcement of the old solutions was to facilitate new solutions.

Comparing the Grant and Berg experiment with the present experiment and that of Youtz the chief difference—aside from the kind of task, which is probably unimportant—is the procedure. Grant and Berg required their subjects to shift five times, and their analysis shows that the effect of increased reinforcement was statistically significant only after the fourth shift of the correct mode of response. As they put it, the confirming function of the reinforcing trials reduced the ambiguity of the situation.

From these studies and the studies of intermittent reinforcement on the extinction of a conditioned response (see Hilgard's discussion (3, pp. 112–113, 124–127)) it is obvious that the simple clear-cut relation between number of pre-shift reinforcements and the rapidity of the shift which was found in the present investigation cannot confidently be extrapolated to other conditions.

Other learning curves.—The learning curves described in this paper are only slightly similar to the conventional learning curves which show a reduction in number of errors or an increase in response speed or amplitude. Equation 2 is similar to the equations published by Thurstone (8), Wiley and Wiley (10), and Hull (4) in that they all describe an approach to an asymptote. But in the previous formulations the ordinate indicates amount learned, while in the present graphs the ordinate describes what is learned in the sense that it locates the center of the scale which the subjects are using. The previous equations are built up by the addition of increments; the present equation is intended to describe an integration, generalization, or patterning of practice effects. For those who like physical analogies the usual learning curves are analogous to the filling of a bucket of water by the repeated addition of small amounts of water, the equation describing the rate of increase. The present curve is analogous to the filling of a bucket of water with water of a different temperature, the equation describing the rate of temperature change of the mixture.

Continuous or discontinuous learning?—Obviously the present theory implies

that the learning is continuous, and the obtained curves, as far as they go, seem to support this notion. It would be interesting, however, to try to arrange conditions which would produce discontinuous learning of scales of judgment. Perhaps if the second series were quite far removed on the stimulus dimension from the first, the subjects would clearly perceive a gap and would therefore segregate the effects of the two discrete sets of experiences. The formation of a scale is presumably a special case of pattern formation; hence other principles of pattern formation would also apply and could perhaps be experimentally demonstrated.

Range of application.—Mathematically the present equation is extremely simple. All it does is specify an initial state of affairs, a final state of affairs, and the transition from the one to the other. Yet, in contrast to the other equations for learning curves it represents the learning by human beings of abstract material of some degree of social significance. The shift in a scale of judgment lends itself readily to this kind of quantitative treatment because the scale can be located on the same dimension before and after the shift and because each judgment of a stimulus-object can be taken as a unit of practice. In respect to the learning of attitudes, social norms, concepts, personality traits, and the like the present formulation seems more pertinent than those derived from the learning of a maze or a discrimination habit.

Summary

The problem is to describe mathematically the shift in a frame of reference or scale of judgment when a person who has been judging one range of frequencies is called upon to judge a higher or lower range. It has been previously demonstrated that the midpoint or limen between the categories 'high' and 'low' is the geometric mean of the frequencies being judged during any one series. If there is a change, upward or downward, in the sounds offered for judgment, the midpoint of the subjective scale will also change, and an equation is written to describe this change as a function of practice with the second series. The equation is based on the assumption that the center of the subjective scale is a moving weighted average of the practice effects left by experience with the stimuli being judged. The data obtained from repeated experimentation agree fairly well with theoretical expectations, indicating that the underlying theory must be approximately correct.

It was further demonstrated that the weight of the first series in retarding adaptation to the second is a function of the number of pre-shift trials with the first series. Some related experiments and the implications of all this for learning theory are discussed briefly.

(Manuscript received January 10, 1949)

References

1. Grant, D. A., & Berg, E. A. A behavioral analysis of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. *J. exp. Psychol.*, 1948, **38**, 404–411.
2. Helson, H. Adaptation-level as frame of reference for prediction of psychophysical data. *Amer. J. Psychol.*, 1947, **60**, 1–29.
3. Hilgard, E. R. *Theories of learning.* Appleton-Century-Crofts, 1948.
4. Hull, C. L. *Principles of behavior.* Appleton-Century, 1943.
5. Johnson, D. M. Generalization of a scale of values by the averaging of practice effects. *J. exp. Psychol.*, 1944, **34**, 425–436.
6. Johnson, D. M. How a person establishes a scale for evaluating his performance. *J. exp. Psychol.*, 1946, **36**, 25–34.
7. Johnson, D. M. Generalization of a reference scale for judging pitch. *J. exp. Psychol.*, 1949, **39**, 316–321.

8. THURSTONE, L. L. The learning function. *J. gen. Psychol.*, 1930, 3, 469–493.
9. TRESSELT, M. E. The influence of amount of practice upon the formation of a scale of judgment. *J. exp. Psychol.*, 1947, 37, 251–260.
10. WILEY, L. A., & WILEY, A. M. Studies in the learning function. *Psychometrika*, 1937, 2, 1–19; 107–120; 161–164.
11. YOUTZ, R. P. The relation between number of confirmations of one hypothesis and the speed of accepting a new and incompatible hypothesis. *Amer. Psychologist*, 1948, 3, 248–249.

ON THE APPLICATION OF ANALYSIS OF VARIANCE TO GSR DATA: II. SOME EFFECTS OF THE USE OF INAPPROPRIATE MEASURES *

BY ERNEST A. HAGGARD

University of Chicago

In an earlier paper (3), four measures of the galvanic skin response, or GSR, were analyzed in terms of the extent to which they met the assumptions underlying the analysis of variance and the *F*-test of significance. These GSR measures were: Resistance change, Conductance change, Log Resistance change, and Log Conductance change. In order to use the above mentioned statistical procedures to make inferences about the parent population, the data resulting from the use of any given measure should at least approximate the characteristics of: additivity, normality, homogeneity of the variances, independence of the means and variances, and randomness. On the basis of the findings of this earlier study, it was concluded that the Log Conductance change measure should be used to quantify the GSR data.

The purpose of the present paper may be stated as follows: If four individuals performed the same experiment, and obtained the same raw data, but if each chose one of four possible measures, or methods of quantifying his data, would the 'empirical results' of each necessarily be comparable? This is in effect what was done in the present study—namely, the four GSR measures were used to quantify the same set of original observations, and the analysis of variance and *F*-test were applied to the resulting four sets of 'data.' Thus, the previous study was done to select a GSR measure on the basis of its scale characteristics; the present one is designed, first, to demonstrate that the indiscriminate application of the analysis of variance and the *F*-test to data with differing scale characteristics, and especially those from measures which do not justify their use, may result in quite invalid conclusions, and second, to attempt to account for the discrepancies among the *F*-values in terms of the qualities of the four measures as they affect the *F*-ratio under identical experimental conditions.

Method and Procedure [1]

Subjects.—A group of 50 boys and 50 girls from the California Adolescent Growth Study (5, 6) served as *S*s when they were 13.5 and later when they were 17.5 years of age.

Variables.—The following three variables were investigated in a factorially designed experiment:

1. *Age*, i.e., whether there is a significant difference in the size of the GSRs of *S*s 13.5 and 17.5 years of age.

2. *Sex*, i.e., whether there is a significant difference in the size of the GSRs of boys and girls.

3. P-I-U, i.e., whether there is a significant difference in the size of the GSR's to words previously rated by the *S*s as being 'pleasant,' 'indifferent,' or 'unpleasant' in emotional tone. There were four stimulus words in each category for each age sample.

Measures.—Three measures of the initial level

* The data utilized in this study were collected by Nathan W. Shock, under the direction of Harold E. Jones, between 1933 and 1938 at the Institute of Child Welfare, University of California, Berkeley.

The present author wishes to express his gratitude to Harold E. Jones for making this study possible while at the University of California.

[1] A description of the apparatus, *S*s, stimuli, etc. is presented in an earlier paper (3).

(nos. 1, 2, 3) and four measures of the GSR (nos. 4, 5, 6, 7) were used. They are:

1. *Initial Resistance:* the resistance level of the *S* at the time the stimulus is presented.

2. *Initial Conductance:* the reciprocal of the initial resistance.

3. *Log Resistance:* the logarithm of measure No. 1, the initial resistance.

4. *Resistance change* (ohms GSR): the difference between the initial resistance and the resistance at the maximal deflection a few seconds later.

5. *Conductance change:* the difference between the initial conductance and the conductance at the maximal deflection a few seconds later.

6. *Log Resistance change:* the difference between the logarithm of the initial resistance and the logarithm of the resistance at the maximal deflection a few seconds later.

7. *Log Conductance change:* the logarithm of the derived measure No. 5, the Conductance change.

Each of these measures was applied to each of 2305 GSRs, 1440 being from the 13.5 and 865 from the 17.5 age samples. After the raw data were tabulated in terms of the four measures, comparisons were made of the *F*-values indicating the significance of the differences among the various conditions of the Age, Sex, and P-I-U variables.

Treatment and analysis of the data.—The computations are based on the mean GSR value for each measure for each of 12 stimulus words for each age sample. Effects due to each variable were analyzed by Fisher's (1) method of analysis of variance, and Snedecor's (7) *F*-test was used to determine the significance levels for each of the various comparisons. No attempt is made in this paper to present or discuss any of the 'findings' of this experiment—as, for example, the decrease in resistance level between 13.5 and 17.5 years of age. Such findings will be reported in subsequent papers intended for that purpose.

Results and Discussion

The findings of this study are of two general types. The first has to do with some of the basic characteristics of the four measures, and especially the relations among these measures which result from the various transformations. The second type of finding is concerned with comparisons of the *F*-values in relation to the three variables that were examined. An attempt will be made to rationalize the wide discrepancies among these statistics in terms of the effects of the particular characteristics of the measures.

The Measures

Table I is presented to show the steps by which each measure is obtained in order to indicate some of the possible effects of the four GSR scales on the ultimate 'empirical results.' In this table, the initial and final resistance levels, and the difference between the two (the resistance change GSR) are given for each of the four sub-groups. The resistance values, which are taken from the original data, are the mean scores for each sub-group. (We may equally well assume that the values entered in Table I refer to a representative response of a representative *S* in each of the four sub-groups.) With these resistance values thus specified, the other GSR's shown in Table I are determined by the nature of the operations used to obtain the derived measures.

In examining these data, it should be recalled that when one transforms numerals by substituting either their logarithms or the reciprocals the effect is to expand the lower end and to contract the upper end of the scale. The relative degree of distortion between the original and the transformed scales is somewhat more pronounced when the reciprocal is used. In view of these considerations, let us examine the effect of each transformation on the four GSR measures.

Measure 4: *Resistance change.*—In this case, no transformation is applied to the raw data, and the GSR is the difference between the *S*'s initial and final resistances. Thus, the average GSR for the 13.5 sample was 10.38 units (or 1038 ohms), and 11.39 units for the 17.5 sample. It should be noted that, according to this measure,

TABLE I

THE MEAN LEVEL AND GSR VALUES FOR EACH OF THE FOUR MEASURES FOR EACH OF THE FOUR SUB-GROUPS

Measures	Units	13.5-Age Sample			17.5-Age Sample		
		Boys	Girls	Av.	Boys	Girls	Av.
1. Initial resistance	ohms $\times 10^{-2}$	700.00	761.00	730.50	262.00	370.00	316.00
Final resistance	ohms $\times 10^{-2}$	691.54	748.70		255.53	353.70	
4. Resistance change GSR	ohms $\times 10^{-2}$	8.46	12.30	10.38	6.47	16.30	11.39
2. Initial conductance	1/ohms $\times 10^{-7}$	142.86	131.41		381.68	270.27	
Final conductance	1/ohms $\times 10^{-7}$	144.60	133.56		391.34	282.73	
5. Conductance change GSR	1/ohms $\times 10^{-7}$	1.74	2.15	1.95	9.66	12.46	11.06
3. Log initial resistance	log ohms	4845.1	4881.4		4418.3	4568.2	
Log final resistance	log ohms	4839.8	4874.3		4407.4	4548.6	
6. Log Resistance change GSR *	log ohms	5.3	7.1	6.2	10.9	19.6	15.3
7. Log Conductance change GSR		2.41	3.32	2.87	9.85	10.96	10.41

* Measure No. 6 is not the Log of measure No. 4, the Resistance change GSR, but rather is the log of the ratio of the initial to the final resistance.

the average GSR's for the two age samples are approximately equal in size.

Measure 5: *Conductance change.*—This measure of the GSR, which is the absolute difference between the initial and final conductance values, averages 1.95 units for the 13.5 sample and 11.06 units for the 17.5 sample. The discrepancy between the relative size of the Resistance and Conductance change GSR's for the two age samples is rather marked, and is a function of the initial resitance levels at which the GSR's were recorded. For example, if the average resistance level for the 17.5 sample had been 116.00, rather than 316.00, the conductance change GSR would have been 121.6 units—assuming that the average Resistance change was still 11.39 units.

Some degree of expansion of the lower end of the resistance scale is justified, however, since the ohms GSR increases with the resistance level (2, 3, 4, 8), but the Conductance scale over-corrects for this bias in the lower resistance ranges (2, 3).

Measure 6: *Log Resistance change.*—For the same two age samples, the average GSR's according to this measure are 6.2 units and 15.3 units respectively. Thus, we see that whereas the average GSR for the 17.5 sample (the lower resistance level) is somewhat larger than the one for the 13.5 sample (the higher level), the relative difference is not so great as when the Conductance change scale is used. This difference is due to the fact that the logarithmic transformation effects a less extreme distortion than does the use of the reciprocal in obtaining such a derived measure.

Measure 7: *Log Conductance change.*—This measure also yields a larger GSR for the 17.5 sample (10.41 units) than for the 13.5 sample (2.87 units). The size of these GSR's, however, is only incidentally related to the initial resistance level. That is to say, the Conductance change GSR's are directly related to the initial level, but in taking the logarithm of the Conductance GSR's, the smaller values (e.g., 1.95) are expanded relatively more than the larger values (e.g., 11.06). Consequently the resulting difference between the two Log conductance change GSRs is less

than it is for the Conductance change GSR's.[2]

The Variables

We have seen that the size of a 'GSR' is dependent to some extent on the *S*'s initial resistance level and on the nature of the measure used to quantify the response. However, can the effect of such factors be sufficiently great to bias the statistical results enough to make the selection of a particular scale worth bothering about? The answer to this question is apparent in Table II, where the respective *F*-values for each comparison are given for each of the four measures.[3]

Variable I: *Age*.—The *F*-values for this variable range from 1.71 to 118.11 —a substantial difference. In order to account for such a range of *F*-values, it is necessary to go back to Table I, where two things should be noted. First, for the Resistance change measure, the average GSR's for the two age groups are about equal, and second, the initial resistance levels for the two age groups are quite different. The fact that the GSR's are similar in magnitude for the Resistance change measure is reflected in the *F*-value of 1.71, which falls at about the .20 level of significance. However, because the use of the reciprocal (or logarithm) distorts the lower end of the original scale relatively more than the upper end, and because the 17.5-age sample has a lower initial resistance, the resultant GSR's are much larger for the 17.5 than they are for the 13.5-age sample when the derived measures are used. Thus, the largest *F*-value (118.11) occurs when the Conductance change measure is used, and in general the *F*-values for this variable are proportional to the degree of distortion introduced when the original resistance measure is transformed.

Variable II: *Sex*.—In terms of this variable, the Resistance change measure yields the largest *F*-value (55.59), and the Conductance change measure the smallest (4.83)—just the reverse of the Age variable. The relative magnitude of the *F*-values for the Sex variable is again germane in Table I. That is to say, the average resistance level for the boys is 481.00 units and is 565.50 units for the girls. However, the average Resistance change GSR for the boys is 7.965 units, but is 14.30 units for the girls. Furthermore, the range of the GSR's for the two age samples is not very great for either the boys (8.46 and 6.47 units) or the girls (12.30 and 16.30 units). The large difference in the numerator, and relatively small variability in the denominator of the significance ratio

[2] The average size of the GSR's for the derived measures is considerably larger for the 17.5- than for the 13.5-age sample, whereas they are approximately the same for the Resistance change measure. One would expect the responses to the 17.5 stimuli to be larger than to the earlier list, inasmuch as they seem to be more provocative. The list for the 13.5 sample is: pleasant (ice cream, sweetheart, funny paper, vacation day), indifferent (tablecloth, lamp shade, waste basket, shirt sleeves), unpleasant (cry baby, castor oil, bad habit, dumbbell). For the 17.5 sample the list is: pleasant (hug mother, beautiful girl, kiss lips, strong muscles), indifferent (book case, wall paper, cloudy day, brush clothes), unpleasant (bloody sore, mean teacher, no money, secret worries).

[3] *F*-values based on responses to individual words vary similarly from measure to measure, but these data are not presented, since Table II seems to offer adequate evidence of the fact that marked discrepancies among the statistical results may occur as a result of variabilities among the characteristics of various measures. Furthermore, the *F*-values for the 'interactions' also vary from measure to measure. This raises the point that (apparently) significant interactions may arise from the use of a non-linear scale to measure linear qualities, or from the use of a linear scale to measure non-linear qualities. One is not able to distinguish between these two cases from the interaction *F*-values themselves.

TABLE II

TABLE OF *F*-VALUES OBTAINED WHEN THE FOUR GSR MEASURES ARE APPLIED TO THE SAME SET OF ORIGINAL OBSERVATIONS*

Measures	Variables					
	Age 17.5 > 13.5	Sex G > B	Stimuli			
			P-I-U	P > I	P > U	U > I
4. Resistance change	1.71	55.59**	15.42**	23.95**	.04	22.11**
5. Conductance change	118.11**	4.83*	15.30**	29.57**	3.49	12.74**
6. Log Resistance change	51.33**	24.20**	15.10**	27.93**	1.86	15.78**
7. Log Conductance change	87.89**	32.30**	25.83**	44.64**	1.33	30.77**
Degrees of freedom	1/36	1/36	2/36	1/36	1/36	1/36

* The comparisons marked with a single asterisk fall at the .05 level, and those marked with a double asterisk fall at the .01 level of significance. Thus, the upper-left comparison (1.71) may be read: according to the measure of Resistance change, the *Ss* in the 17.5 sample showed larger GSR's than the *Ss* in the 13.5 sample, but this difference is not significant. The designation of the number of degrees of freedom (1/36) is to be read: one d.f. in the numerator and 36 in the denominator of the *F*-ratio.

results in the large *F*-value for the Resistance change measure.

For the Conductance change measure, however, the average GSR is 5.70 units for the boys and 7.305 units for the girls, a difference between the GSR means which is a good deal less than in the case of the Resistance change measure. In addition, the variability among the GSR's for the two age groups is much greater, both for the boys (1.74 and 9.66 units) and the girls (2.15 and 12.46 units). Thus, as compared with the Resistance change measure, the difference in the numerator of the significance ratio is decreased and the variability in the denominator is increased. The result is a much smaller *F*-value. The remaining two measures, which show less extreme variations in this respect, also yield intermediate *F*-values.

Variable III: *Pleasant-Indifferent-Unpleasant stimuli.*—Whether one considers comparisons among the P-I-U conditions taken together, or between the P-I, P-U, or U-I conditions taken separately, it is readily apparent that the variability among the *F*-values is much less than in the Age and Sex variables. Actually, the conditions which operated to effect a wide range of *F*-values in the case of the previous variables are now found to contribute toward the consistancy of the *F*-values for the P-I-U variable. That is to say, the importance of the initial level in introducing differential distortion in the transformed measures is minimized, since each of the sub-groups in the Age and Sex variables contributes toward each of the P, I, and U conditions. As a result, the denominator of the significance ratio tends to be more uniform for each of the P, I, and U conditions, so that the *F*-values tend to be more uniform than in the case of the previous variables.

There is one exception to this uniformity in the P-I-U variable—namely, that the *F*-value for the Log Conductance change measure is largest in the P-I-U, P-I and U-I comparisons. This is probably due to the fact that the other three measures show a significant degree of hetero-

geneity among the variances from sample to sample, whereas the Log Conductance change measure does not (3). The effect of the homogeneity among the variances of the Log Conductance change samples is to reduce the denominator, or error estimate, of the significance ratio, and hence to increase the size of the *F*-value. Also, because of the heterogeneity characterizing the other three measures, it seems safe to assume that the *F*-values yielded by them are biased in the direction of being too small.

In conclusion, no attention has been paid in this paper to 'results' in the customary sense of the term. Rather, an attempt has been made to show that with a given set of original data, a wide range of such 'results' might be obtained, depending on the particular characteristics of the measures and statistical tests used. But the existence of such wide discrepancies among the *F*-values reported in this paper does not mean that relatively stable and precise findings cannot be obtained. It only means that one should know the nature of his scale of measurement, and that its characteristics should correspond to the assumptions underlying the methods of statistical analysis to be used. In other words, any of the four measures of the GSR examined in this paper might be used if one only wishes to determine, say, percentile ranks, but they cannot all be used if one wishes to use such refined techniques as analysis of variance.

Summary

The purpose of this paper is to apply four measures of the GSR to a given set of original data, to show that the application of the *F*-test to inappropriate measures results in invalid conclusions, and to attempt to account for discrepancies among the *F*-values in terms of the qualities of the four measures as they affect the *F*-ratio under identical experimental conditions. The GSR measures include: Resistance change, Conductance change, Log Resistance change, and Log Conductance change. Comparisons were made in terms of certain scale characteristics of the four measures, and in terms of the variables of Age, Sex, and P-I-U (words previously rated by the *Ss* as being 'pleasant,' 'indifferent,' or 'unpleasant' in emotional tone). A group of 50 boys and 50 girls were tested at 13.5 and retested at 17.5 years of age. The study is based on 2305 responses.

The findings of this study justify the following conclusions:

1. The four GSR measures examined in this study cannot be used interchangeably, since when applied independently to the same original scores, some measures yielded highly significant differences for a given comparison, whereas others did not.

2. The variability among the obtained *F*-values arises from the scale characteristics of the four measures as they are applied to the original or derived scores. It may be assumed that those measures which violate the basic assumptions underlying the analysis of variance technique yield biased *F*-values.

(Manuscript received January 20, 1949)

References

1. Fisher, R. A. *Statistical methods for research workers.* (9th Ed.) Edinburgh: Oliver and Boyd Ltd., 1944.
2. Haggard, E. A. Experimental studies in affective processes: II. On the quantification and evaluation of 'measured' changes in skin resistance. *J. exp. Psychol.*, 1945, **35**, 46–56.
3. Haggard, E. A. On the application of analysis of variance to GSR data: I.

The selection of an appropriate measure. *J. exp. Psychol.*, 1949, **39**, 378–392.

4. HAGGARD, E. A., & GARNER, W. R. An empirical test of a derived measure of changes in skin resistance. *J. exp. Psychol.*, 1946, **36**, 59–70.
5. JONES, H. E. The California adolescent growth study. *J. educ. Res.*, 1938 **31**, 561–567.
6. JONES, H. E. The adolescent growth study: I. Principles and methods, II. Procedures. *J. consult. Psychol.*, 1939, **3**, 157–159, 177–180.
7. SNEDECOR, G. W. *Statistical methods.* (4th Ed.) Ames, Iowa: The Collegiate Press, Inc., 1946.
8. WENGER, M. A., & IRWIN, O. C. Fluctuations in skin resistance of infants and adults and their relation to muscular processes. *Studies in infant behavior, III. Univ. Ia. Stud. Child. Welf.*, 1936, **12**, No. 1, pp. 143–179.

CONDITIONED GENERALIZATION OF THE GALVANIC SKIN REACTION TO TONES[1]

BY RICHARD A. LITTMAN

University of Oregon

I. Introduction

Recent years have seen a serious attempt to state theoretical principles in a form that permits the rigid deduction of testable propositions. These statements must necessarily take a quantitative form and the formulations of Clark Hull have given this method its greatest impetus. Fundamental to Hull's systematization of behavior theory is the phenomenon known as generalization. It provides one of the bases for explaining secondary reinforcement, reactions to compound stimulus patterns, etc.

The empirical status of generalization as understood by most workers in the field of learning (*cf.* Hull (16), McGeoch (21), and Spence (25) for illustrations) has been questioned recently by Lashley and Wade (19). The latter suggest that it is an artifact and is not a function of learning. They propose, further, that the term generalization be restricted to the consequences of some form of differential training. Hull (17) has recently replied to these attacks and utilized as a major line of evidence the results of an intensive series of investigations by Hovland (12, 13, 14, 15), the precise quantitative statement of the generalization function being derived from them.

Other investigators have questioned Hull's definition, using, as did Lashley and Wade, their own experiments as sources of evidence. For example, Schlosberg and Solomon (24) have proposed that the generalization curve is a straight line in contrast with the negative growth function assumed by Hull and obtained by Hovland. Grandine and Harlow (7a) have also reported generalization taking the form of a straight line.

However, these different notions are based on specific experimental procedures which differ for each set of results. In this sense none can be considered as a criticism of any other; strictly, they are irrelevant. They do, however, clarify the probable range of any set of results. It would seem desirable, therefore, to attempt to *verify* some set of findings rather than to establish negative instances by the use of different techniques. We have selected the type of procedure used by Hovland in an attempt to establish his results on a more secure footing. The generalization to tonal frequency was selected as the most likely place to check since in Hovland's work this dimension yielded the clearest results. The generalization to loudness, while revealing a similar pattern, was somewhat more ambiguous.

As described below the procedures of Hovland were followed as exactly as practicable, though in regard to instrumentation, selection of equal loudnesses, and the statistical method of analysis it was necessary to introduce variations. These latter considerations are of great weight in interpret-

[1] The experimental portion of this study was carried out at Indiana University under the direction of Dr. R. C. Davis. We wish to thank him for his continued aid, and also Drs. D. Bakan and D. D. Wickens of the Ohio State University for their valuable suggestions. An abridged version of this paper was read before the Midwestern Psychological Association in May, 1948.

ing Hovland's data. Consequently, this paper contains an intensive critique of the procedures used in his investigation. We believe that the problems raised merit such extended treatment in view of the differences which investigations of generalization have already yielded.

II. Subjects

Twenty-two subjects were used in the main portion of the experiment. They were divided into two groups of 11 subjects each. All were freshman students of introductory psychology and were naive as to the purpose of the study. Each subject served under only one experimental condition. Upon entering the experimental room the subjects were requested not to ask any questions with the promise of an explanation at the end of the session. At that time they were told it was a study in relaxation. While all were cautioned against revealing their experiences to other subjects, there was some indication that this was violated in several instances. We are unable to ascertain the effect that this had upon the results, though studies by Miller and Cole (22), Hilgard and Humphreys (10) and Wickens (27) indicate that genuine conditioning does occur in spite of a variety of sets of an inhibitory or facilitating nature.

III. Apparatus

A. *Place.*—Two rooms were used in this study. The subjects passed through the screened-off experimenter's room to a long, rather narrow, high-ceilinged room painted lamp-black. They were seated in a comfortably upholstered rocking chair with fixed chocks behind, and in front of, the rockers.

B. *Shock.*—Polished brass electrodes were attached above the left wrist on the outer and inner surfaces of the arm. They were about the size of a quarter and were fastened down by a black cheesecloth thong. The power supply was obtained from four 1½-volt dry cells in series with a Porter inductorium. The amount of shock, in volts, was determined in the fashion described under Procedure. During the two weeks of the study there were no changes in the power supply.

C. *GSR*

1. *Electrodes*

a. *Construction.*—A polished zinc disc with a lead soldered to its back was wedged inside a radio vacuum tube base which had been cut down to a height of approximately ¾ in. This was covered with a thin layer of dampened manganese-dioxide; on top of this a felt plug was placed which projected beyond the surface of the shell and contacted the subject's palms. Prior to placing the electrodes in position the felt was moistened with a physiological salt solution. This type of electrode is relatively non-polarizable (5) in contrast with the polished silver coins used by Bass and Hull (1) and Hovland (12).

b. *Location.*—One electrode was attached to each palm. In Hovland's study the electrodes were attached to the palm and back of the same hand. There is some evidence to indicate that the electrical reactions of the skin surface are not the same at all points, frequently being mediated by different processes. Thus, Davis (5) reports that the electrical reactions on the back and palm of the hand are very different, the latter giving a true GSR, mediated by neural structures, while the former, lacking many sweat glands, has a higher level of resistance and evinces what may be a local reaction. It was decided therefore to utilize a reaction whose functions are fairly well known rather than a complex one which might introduce unknown variations, e.g., differences in the latency period, magnitude of drop in apparent resistance, differences in adaptation rates, etc.

2. *Galvanometer*

a. *Instrument.*—The device used is described in the articles by Davis (4) and Davis and Porter (6). The advantages of such an electronic measuring instrument over the Wheatstone Bridge using a string galvanometer have been fully explored by Davis (4). Hovland used a d'Arsonval reflecting galvanometer (L & N Type R no. 2500b) of the ballistic type which has a period of six sec. Since the GSR has a latency of approximately three sec., interpretation of results obtained with such an instrument is difficult. Electrical recordings so obtained will represent a state of affairs somewhere between the true initial resistance changes and the loss at the time of the galvanometer's maximum response. Also, different rates of response change will produce differential deflections, the faster the change the larger the reading, magnitude being constant. It is to be noted that the nature of the error introduced affects both latency and magnitude measures, though Hovland used only the latter. This is to be expected where the natural period of the recorder exceeds that of the reaction which it is measuring. In contrast, the speed of the vacuum tube reaction is well within these limits.

b. *Recording.*—A distinctive source of error in Hovland's study appears to result from the insertion of a potentiometer into the circuit to restrict the range of reactions from subject to subject within a narrow limit. This is a questionable procedure, since the extent of the GSR

is a function of its absolute level. Humphreys has indicated that while this would make the SD's and SE_m's 'spuriously low,' the standard error of the difference would be unaffected because the "restriction of range is compensated for by reduced correlation coefficients (**18**, 362)." Since there is some question as to whether the correlation coefficients in this situation are linear, the degree of reduction, however, would not be a constant value but would vary as a function of the general level of reaction for the specific subject and his particular rate of adaptation. In such a case the ordinary sampling error formulas are inappropriate.

c. *Calibration.*—By calibrating the galvanometer with a set of resistance boxes the absolute level of resistance in ohms was determined. After conversion into absolute resistances our data were further treated to yield the final scores described under the Procedure. The galvanometer was calibrated twice during the experiment but no changes in its characteristics were noted.

D. *Timing.*—The time intervals were the same as Hovland's. A wooden commutator disk driven by a constant speed phonograph motor determined the intervals. The timing was chronoscopically established taking account of speed pick-up from a fixed starting point.

E. *Auditory stimuli*

1. *Generator.*—The tones were generated by a Western Electric 6B Audiometer with a Western Electric 700A headphone matched to the audiometer and rated in db's at the ear. Only one phone was used, and it was set to the subject's preferred ear with a dummy phone on the other to balance the headset. While the 6B audiometer has a continuous frequency band, it is marked-off in octave units from 128 c.p.s. Therefore, the locations of the tones used in the study were determined oscillographically, and the db values at these points rechecked. No noticeable click occurred at the phone when the tones were administered through the timing device.

2. *Frequency.*—The tones were 153, 468, 1000, and 1967 c.p.s. As determined by Hovland, they are 25 JND's apart and presumably establish equal units for a generalization scale. However, Humphreys (**18**) has demonstrated the untenability of this proposition, by showing octave effects. Thus, the method of equal-appearing intervals would seem better suited to establish 'equal units' within the auditory dimension. Since, however, our purpose was to repeat Hovland rather than to introduce unknown variations, these same tones were used.

3. *Loudness.*—After the desired loudnesses were known the audiometer was recalibrated using the same base as in the design of the audiometer circuit.

IV. Procedure

A. *Preliminary*

1. *Loudness of tones.*—The audiometer was used to establish equal loudnesses with a preliminary group. The 1000 c.p.s. tone, set at 40 db, was used as the base to which the other tones were equated. The results of the first two subjects were checked against the Fletcher and Munson contour curve of equal loudnesses as adapted by Stevens and Davis (**26**, p. 123, Fig. 44). Our data fitted these plots almost exactly, and it was decided to use the values thus obtained. This decision was justified by the experimental results, for the reactions to the tones did not differ significantly from one another prior to conditioning. This problem is further discussed under Results.

2. *Shock level* (*UCS*).—One week before the actual conditioning process each subject was tested for the strength of the shock to be used when he was conditioned. He was seated in the same chair and room to be used later and was instructed as follows: "Today we will decide the amount of shock to be used next week. You are to say when it is uncomfortable but not painful." The four 1½-volt cells were fresh and the intensity of delivery was measured in terms of distance on the secondary of the inductorium. The shock electrodes were attached to the left wrist, the subject was put in the GSR circuit, and the phones, though dead, were placed on his head. On the same type of inductorium, Hovland's subjects had a range of 3.8 cm. to 6.9 cm. on the secondary, with two cells in series. Our subjects ranged from 3.7 cm. to 7.3 cm. on the secondary with a mean of 5.5 cm. The setting finally selected, in each case, elicited a 'healthy' GSR of approximately the same magnitude obtained one week later during initial phases of conditioning.

B. *Main prodecure*

1. *Adapting subject.*—The secondary on the inductorium was adjusted for each subject before he appeared and the galvanometer was turned on to avoid warming-up delays. *S* was comfortably seated and the headphones and electrodes were adjusted to him. *E* instructed him as follows: "Make your mind a complete blank but don't fall asleep. Don't think about the experiment but don't get too relaxed." *E* then left the room and adjusted the galvanometer until A appeared to be stabilized. This took from one to four min. (preliminary data), so five min. was set as an arbitrary limit. All the subjects held fairly steadily at this time, though, of course, the absolute levels varied considerably. At this point *E* began the conditioning procedure.

2. *Conditioning.*—Following a predetermined rotation schema, the four tones were presented

to each subject twice, unpaired with shock; then two shocks alone were administered. These represented the reaction-level to the CS and the UCS prior to conditioning. After the two shocks the CS and the UCS were paired for 16 trials. This was followed by four tests each of the CS and the three other tones (the generalization stimuli) for a total of 16 CR tests, again according to a rotation schema.

These latter tests are hereafter called cycles. There were four cycles, each one containing the four tones. Since the tones were rotated differently for each subject per cycle, the results for each conditioning set-up could safely be combined and analyzed by cycles.

3. *Grouping.*—There were two CS's and thus two groups. In Group I the CS was the tone of 153 c.p.s. with 468, 1000 and 1967 c.p.s. being the tones tested for generalization. In Group II, 1967 c.p.s. was the CS with 1000, 468 and 153 c.p.s. being the generalized stimuli in the order of removal. These will hereafter be referred to in the following manner:

Conditioned Stimulus		
Group I	Group II	Symbol
153 c.p.s.	*1967 c.p.s.*	
153 c.p.s.	1967 c.p.s.	0
468 c.p.s.	1000 c.p.s.	1
1000 c.p.s.	468 c.p.s.	2
1967 c.p.s.	153 c.p.s.	3

Where the context is not clear the underlined digit will be preceded by, e.g., I2. The schedule was determined by the subject's convenience and membership in his conditioning group was on an approximate alternating basis, with the first two subjects going into Group I, the next two into Group II, and so on.

4. *Conditioning and recording*

a. *Timing.*—A short trace classical conditioned response was used. The CS appeared for 400 msec., there followed a 95 msec. pause and then the shock was administered for 75 msec. One trial therefore took 570 msec. The switch box used permitted control over the stimuli so that they could be selectively administered. These are the same intervals used by Hovland.

b. *Distribution of practice.*—Each subject gave a total of 42 GSR's. Stimuli occurred at approximately one-min. intervals. Since the GSR takes about 30–35 sec. to recover if the stimulus is not too severe, any stimulation within this period evokes a negligible reaction, and a 'rest' period of at least this length must be provided. After two or three stimulations in a regular manner, *Ss* usually show considerable anticipatory activity and *E* therefore adopted the policy of 'waiting-out' or anticipating the *S*'s anticipation. This meant that actual stimulation was not at a specific interval after the previous stimulation but varied. The actual intervals were between 45–75 sec. Thus, while the mean interval was approximately 60 sec., there was very little consistency and *S* did not have a stable reference frame spanning so short a period that he could set up a CR independent of the tone and based purely upon time relations. This seemed to be a satisfactory procedure, the amount of anticipation (drop in resistance) decreasing markedly before the pairing process was completed.

c. *Recording and quantification.*—*E* recorded resistance from a milliameter before and after stimulation. If the meter at any time went off-scale due to an excessive reaction, or the natural drift resulting from the steady adaptive lowering of apparent resistance, *E* set it back on scale (only the central portion of the dials were used). The pre-stimulation resistance recorded was that which appeared at the moment of stimulus administration. The post-stimulation resistance drop was defined as the maximum deflection of the milliameter indicator. There was little difficulty in deciding when this point of maximum drop had been reached. The actual resistances in terms of ohms were then computed for both pre- and post-stimulation in terms of a calibration curve set up for the instrument at the beginning of the investigation, and checked about half-way through. These absolute resistances were then treated as follows. A ratio between the pre- and post-stimulation resistances was obtained for each reaction. This value expresses the degree of drop in resistance as a function of the absolute level of resistance, a necessary precaution. Such a procedure gives results similar to the log conductance scale proposed by Darrow (**3**) without making further assumptions as to the specific function involved. The procedure of Haggard (**8**) would seem to give quite comparable results, since it is based on the same rationale. Our quantities then are ratio differences, i.e., one minus the ratio of pre- and post-stimulation. Since the analysis was performed with IBM equipment, these quantities have been multiplied by 100; 500 was then added to eliminate negative values (*cf.* Fig. 2).

5. *Exit interview.*—Upon completion of the session each subject was asked if he had guessed the nature of the experiment and if he could relate the sequence of events. Since no systematic analysis of these responses will be presented, it seems proper to indicate the general picture at this point. Almost every subject 'caught on' to the procedure in the sense of understanding the temporal sequence during pairing. "I knew as soon as I heard the tone that I was going to get stung," is a typical comment. None mentioned,

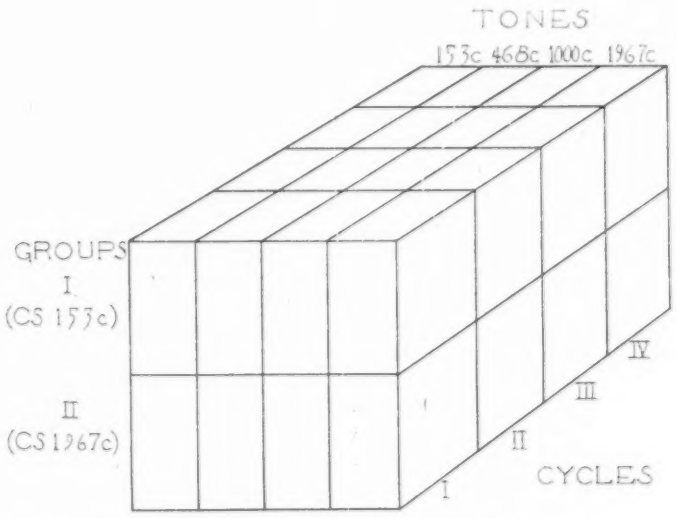
or recalled, the onset or cessation of the pairing procedure. However, while voluntary conditioning seems to present some difficulties (**10**) and, specifically, while the galvanic CR is modifiable by instructions (**2**), symbolic factors seem unable to eliminate the reaction. On the other hand, these symbolic features of self-administered instructions seem quite capable of enhancing a 'conditioned' galvanic reaction (**21**). However, as Hilgard and Marquis suggest, in the absence of instructions from *E* the conditioned GSR ". . . seems to be following the typical course of conditioning (**11**, p. 267)." Most likely, then, we are dealing with some sort of interaction rather than a simple or spurious conditioning process.

V. Statistical Procedures

The data in this study have been analyzed by the methods of analysis of variance: a detailed description follows. Graphically the design may be visualized as in Fig. 1. There were two groups, one conditioned to the tone of 153 c.p.s. (Group I) and the other to the tone of 1967 c.p.s. (Group II). Each group was analyzed separately, and the treatment described below was thus carried out twice in all details.

The total variation of the scores involved in this investigation has been broken down into two major sources of variation: within and between sub-groups. The within-groups sums of squares and degrees of freedom have been broken down into seven sources, and these are given below Fig. 1. The cycle by tone by individual interaction was taken as the error term for the evaluation of the other sources of variation within each group. When the two groups were compared, it was found that their variances differed significantly, and thus no further comparisons of Groups I and II were attempted.

We have used a very precise measure as the error term. Preliminary analysis with the usual formula for the significance of the differences



Source of Variation	df	Source of Variation	df
Cycles	3	Cycles by individuals	30
Tones	3	Tones by individuals	30
Individuals	10	Cycles by tones by individuals	90
Cycles by tones	9	Total	175

Fig. 1. This figure shows the major experimental variables and the possible modes of interaction. The breakdown into sources of variation (below the figure) represents the method of analysis within *each* group. Thus each cell contains 11 individuals and it is they, rather than the group, who are analyzed as a source of variation. The degrees of freedom associated with each source are given and the total df is the sum for only one group. The cycles by tones by individuals interaction constitutes the error term. The analysis was carried out for each group separately.

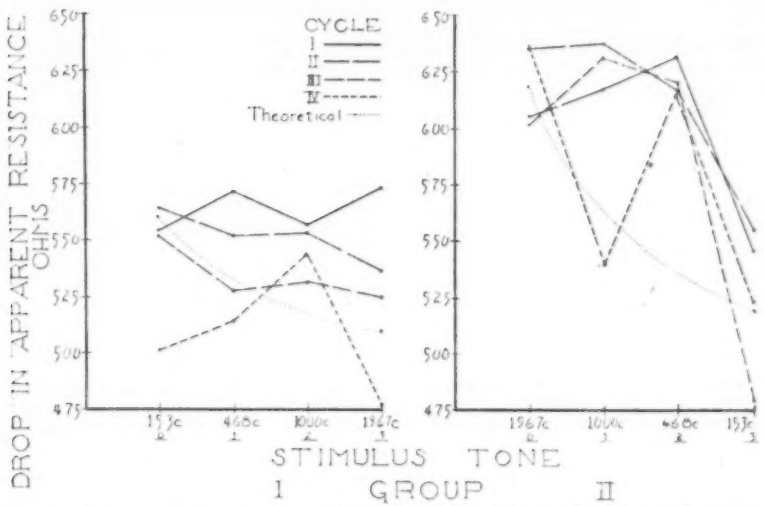


FIG. 2. Group I (CS = 153 c.p.s.) and Group II (CS = 1967 c.p.s.). Curves of conditioned stimulus generalization. The drop in resistance to the tonal stimulus is expressed as the difference between pre- and post-conditioning magnitudes. The smooth curve is a theoretical one, and is inserted as an illustration of the type of curve obtained by Hovland. Note that the ordinate is not really a scale of ohms but a transformed score based on the ratio between resistance prior to stimulation and after stimulation.

between correlated measures yielded several *t*'s which indicated differences between the CS and several of the tones. However, as this was a theoretical rather than an applied investigation, it was decided to remove the variation associated with the individuals used, and obtain an error term as purely the result of chance variation as possible under the present circumstances. This procedure, as may be seen below, eliminated the differences which had been obtained by less sensitive measures.

In the absence of a general function such as *F*, it is of questionable value to compute a large number of *t*'s, since we should expect a certain number of them to be significant on a chance basis. The major concern in that case lies in the fact that there is no way of telling which are the spurious values; they may well be the ones upon which the major part of the argument rests. Having obtained *F*, specific comparisons by means of the *t* statistic may then be carried out subject only to restrictions laid down by the degrees of freedom available. The use of analysis of variance in our study meets this type of criticism.

VI. RESULTS

A. *Pre-Conditioning.*—In order to demonstrate the occurrence of conditioning the CS must be shown to differ initially from the UCS. Table II shows that for each tone, in both groups, the reaction is significantly smaller than the reaction to shock. On the other hand, an analysis of variance revealed that, within each group, the tones did not differ from one another, the error variance exceeding the variance due to tones.

The reader will recall that Hovland pooled the data for both of his groups because there were no significant differences between them. Our results do not permit us to follow this procedure. When the variances of the two groups were tested for homogeneity of variance a significant difference was obtained. There is no reason at hand to explain these differences and they are most likely the result of chance selection factors.

B. *Post-Conditioning.*—Fig. 2 contains plots of mean difference scores,

TABLE I

Table of mean reaction levels, all subjects combined, by cycle. These are coded scores and obtained by subtracting the value of the reaction to the tone before conditioning from the value after conditioning, plus 500. Values are rounded.

	Group I (CS 153)				Group II (CS 1967)			
	153 c.p.s.	468 c.p.s.	1000 c.p.s.	1967 c.p.s.	1967 c.p.s.	1000 c.p.s.	468 c.p.s.	153 c.p.s.
Cycle I	554	572	557	574	605	617	631	546
Cycle II	564	552	553	537	635	637	617	555
Cycle III	552	528	532	525	602	631	620	478
Cycle IV	501	514	544	477	636	540	614	523

TABLE II

Significance of the differences between the reactions to the UCS (shock) and the CS's (tones) prior to conditioning, when the reactions to the tones do not differ among themselves per group, and the F between group variances is significant at the five percent level. The null hypothesis is being tested.

	Tone.....	153 c.p.s.	468 c.p.s.	1000 c.p.s.	1967 c.p.s.
Group I (CS 153)	Diff. of shock and tone means	183	207	206	199
	t*	3.04	3.44	3.42	3.30
	Tone.....	1967 c.p.s.	1000 c.p.s.	468 c.p.s.	153 c.p.s.
Group II (CS 1967)	Diff. of shock and tone means	138	192	181	182
	t*	4.34	6.05	5.70	5.73

* Value of t must exceed 2.764 to be significant at the two percent level.

TABLE III

Analysis of variance of the results of conditioning. The error term is the cycle by tone by individual interaction and $df = 90$. The between-group F for the total variance is 2.16 ($P<.01$), indicating heterogeneity of variance. Higher-order interactions take their names from the first letter of the main effects.

Source of Variation	df	Group I (CS = 153)		Group II (CS = 1967)	
		F-ratio	P	F-ratio	P
Cycles	3	8.51	<.01	25.56	<.01
Tones	3	2.11	>.05	226.27	<.01
Individuals	10	14.07	<.01	535.77	<.01
C × T	9	2.92	<.01	40.90	<.01
C × I	30	7.67	<.01	23.85	<.01
T × I	30	4.70	<.01	79.52	<.01
C × T × I	90				
Total	175				

i.e., the difference between the reaction level to the CS's before and after conditioning. Table I gives the transformed difference scores used in drawing the graphs and making the analysis. As might have been expected from the preconditioning relationships, the variances of Group I and Group II differ significantly (Table III): F is 2.16 and $P<.01$. Therefore, we shall discuss the two groups separately and, in a third section, discuss the similarities and differences which are apparent.

1. *Group I.*—It is evident from the F's in Table III that, after conditioning, the means of the tones differ significantly among themselves, whether

considered by cycle or by individual or by cycle by tone. This permits us to make systematic use of the *t* statistic in an attempt to locate the source of these differences. Analysis indicated that all the tones differed significantly from their pre-conditioning value beyond the one percent

TABLE IV

Significance of the differences* between the reactions to tones after conditioning; by cycles, each tone with self. The symbol + means cycle II, III, or IV is greater than cycle I in reaction magnitude.

		Group I (CS = 153)					Group II (CS = 1967)				
		Total Cycle	153 c.p.s.	468 c.p.s.	1000 c.p.s.	1967 c.p.s.	Total Cycle	1967 c.p.s.	1000 c.p.s.	468 c.p.s.	153 c.p.s.
Cycle I minus II	Diff.	12.79	+10	20	3	37	+11.57	+30	+20	14	+11
	t	1.15	.45	.89	.13	1.64	2.71	3.51	2.34	1.64	1.29
Cycle I minus III	Diff.	30.04	2	44	25	49	16.93	3	+14	11	68
	t	2.70	.08	1.97	1.12	2.20	3.96	.35	1.64	1.29	7.95
Cycle I minus IV	Diff.	55.22	53	58	13	97	21.48	+31	77	17	23
	t	4.96	2.38	2.60	.58	4.36	5.03	3.62	9.00	1.99	2.69

* The error term is computed by Lindquists formula (20, p. 102) for determining *t* after *F* has been ascertained. With 90 *df* taken as an ∞ sample, *t* must exceed 1.96 at the five percent level and 2.57 at the one percent level.

TABLE V

Significance of the differences* between conditioned reaction and the response to the three generalization stimuli after conditioning, by cycles. The symbol + means that the reaction of the generalization stimulus exceeds the conditioned reaction.

		Group I (CS = 153)					Group II (CS = 1967)				
	c.p.s.	153 c.p.s.	468 c.p.s.	1000 c.p.s.	1967 c.p.s.	c.p.s.	1967 c.p.s.	1000 c.p.s.	468 c.p.s.	153 c.p.s.
Cycle I	153		+18	+3	+20	1967		+12	+26	59
	468	.81		15	2	1000	1.40		14	79
	1000	.13	.67		17	468	3.03	1.64		85
	1967	.88	.09	.77		153	6.91	8.22	9.95	
Cycle II	153		12	11	27	1967		+3	18	80
	468	.54		1	15	1000	.35		21	83
	1000	.49	.04		16	468	2.11	2.46		62
	1967	1.29	.67	.71		153	9.37	9.72	7.26	
CycleIII	153		25	20	27	1967		+28	+17	125
	468	1.12		5	2	1000	3.28		11	153
	1000	.88	.22		7	468	1.99	1.29		142
	1967	1.21	.09	.23		153	14.63	17.91	16.63	
Cycle IV	153		+13	+43	24	1967		96	22	113
	468	.58		30	37	1000	11.24		74	17
	1000	1.93	1.34		67	468	2.58	8.66		91
	1967	1.08	1.66	3.01		153	13.23	1.99	10.65	

* The *t*'s were computed according to the same formula given in Table V. The left section of each matrix contains the *t* scores, and the right half the raw differences between the scores. For 90 *df*, 1.96 is significant at the five percent level and 2.57 at the one percent level.

level;[2] this is true for all four cycles. When inter-cycle differences are considered we note (Table IV) that cycles III and IV differ from cycle I, when all the data for a given cycle are pooled.[3] This procedure is not very fruitful, however, and it is the differences in tones by cycle that locate the most likely source of the significant *F*'s. Tones 1 and 3 show the greatest change inter-cyclically (Table IV), with a rather systematic decline in magnitude that is most likely the beginning of extinction. At all times, however, these tones continue to be significantly different from their preconditioning level. Tone 2 shows an equally systematic decline in terms of raw scores; however, none of the points in cycles II, III, or IV differ from the cycle I level. In cycle IV the CS differs from the cycle I level, being significantly smaller. In view of the erratic nature of this cycle there would seem to be some justification in rejecting it as being in some way faulty, but, since these are pooled data for different subjects, this would be a difficult decision to justify. If we look at the actual difference data, it is apparent that tone 2 is much less variable than any of the others except for the CS in the first three cycles, and retains approximately the same level on the fourth cycle. If we turn for a moment to Fig. 2 for the data of Group II, it will be seen that tone 1 (which is the same as 2 in Group I in terms of frequency) in cycle IV returns to a level which is about the same as that at which the same tone functioned in Group I in all four cycles. It would seem, therefore, that this tone may have had some factor in it which maintained the reaction at a certain level and gave it relatively greater stability, perhaps some cochlear phenomenon. The reader will recall that this tone was the base in determining the loudness levels used and therefore may have differed in loudness from the other tones. While the initial response levels were equal, threshold differences might have been undetected and been influenced in some systematic nature by the conditioning process.

One cannot miss the distinct flatness of the curve for cycle I, and Table V reinforces this impression. All the tones are of equal magnitude, indicating that the increment in the evocative strength of the generalization stimuli may be equal to that of the CS. Exactly the same picture may be seen for cycles II and III. It is only in cycle IV that any intra-cycle differences appear, and it is especially noteworthy that it is the *t* in which tone 2 is involved that shows this difference, i.e., the *t* between tones 2 and 3.

[2] For purposes of simplicity of style we refer to the *tone* as showing a particular reaction level. Obviously it is not the tone which shows the reaction, and we refer to the magnitude of the reaction to the tone or the shock.

[3] In the studies of Bass and Hull, and of Hovland, an unusual procedure was followed in establishing the form of the generalization curve. The data for the first two cycles after conditioning were combined. There are at least two consequences of this operation. Unless there is a great deal of variability, more stable values will be achieved. On the other hand, certain trends or patterns may be obscured. Since conditioning is a dynamic process, each cycle is independent in one sense and interrelated in another. Thus, inspection of the raw data for the first two cycles of Hovland's results indicates that the first cycle gives a much shallower curve than the second. By combining them, a mean value which sharpens the true drop from CS to generalization stimuli is obtained. If the generalization stimuli are more susceptible to extinction than the CS, as Hovland's data appear to establish, then the major impact of this combining technique will fall on just those reactions in which we are most interested. With this in mind we have kept the analysis of our data separate for the different cycles. This problem is more thoroughly discussed below.

To summarize the facts for Group I:

(1) The tones do not differ among themselves initially.

(2) All tones differ from their preliminary level after the conditioning of only one tone (153 c.p.s.); i.e., generalization has occured.

(3) Inter-cycle differences do not appear until cycles III and IV for the mean of all tones, or for the tones taken separately.

(4) There are no intra-cycle differences until the fourth cycle.

2. *Group II.*—A parallel analysis for Group II may be made. Whether we consider the *F*'s in Table III by tone, by cycle, by individual, or by cycle by tone they are all highly significant. The *t* statistic is therefore permissible. All of these tones differ at a high level from their pre-conditioning values. Thus, we may conclude that both conditioning and generalization have been established. If we turn now to the mean score per cycle for all tones, we find that all three cycles differ significantly from cycle I (Table IV). When inter-cycle differences are considered by tone (Table IV), the differences between Groups I and II stand out. In Group I the changes and relations were quite regular and their meaning clear. For Group II we note immediately that the CS shows a significant rise from cycle I to cycle II, a regression in cycle III and finally a significant rise in cycle IV. The generalization tones are similarly erratic. Tone 1 rises and then falls to a very low level by cycle IV; the possible implications of this were discussed with regard to tone 2 of Group I. In this group tone 2 is quite stable; while the raw values drop, they do not do so at a significant level, until the fourth cycle. Tone 3 functions at a low level in all cycles.

An analysis of the intra-cyclic relations supports the eccentric nature of these observations. With the exception of tone 2, which does not differ significantly from the CS in cycles I and II, all the tones differ from the CS in all cycles (Table V). The general pattern for this group is too erratic to permit further elaboration of the results.[4]

To summarize Group II:

(1) The tones do not differ among themselves initially.

(2) All tones differ from their preliminary levels after CS1967 was conditioned, i.e., generalization has occurred.

(3) Inter-cyclic differences appear upon the second cycle.

(4) Intra-cyclic differences appear in the first and all succeeding cycles.

3. Groups I and II considered jointly: As indicated above, the variances of the two groups differ and therefore the data cannot be combined or contrasted on a formal basis. Nevertheless, on a descriptive level it appears reasonable to point out similarities between the two groups. The major characteristic to note is, in a sense, a negative one. The generalization stimuli do not show, except for tone 3 in Group II, any systematic tendency to drop far below the CR. They are either equal to the CR, which is the Group I pattern, or actually exceed its level, which is, in part, the Group II picture.

VII. Discussion

A.—The results of this study confirm only in part those obtained by

[4] These results point up an interesting phenomenon. In exploratory sessions it was noted that the generalization tones most frequently showed increments *before* the CS began to show any clear-cut variation. This may indicate the existence of some sort of sensitization, rather than a generalization, process, but any definitive determination awaits research pointed specifically at the phenomenon as a problem.

Hovland. There are at least three major possibilities for these differences; differences in the loudness of the tones, in the degree of conditioning, and in the statistical procedures.

1. *Tones.*—Since the two studies used different equipment to generate and transmit the signals the loudnesses cannot be directly compared. While the power base for db determination is available for the generators, transmission differences, mainly at the earphones, prevent an accurate estimate. There is, however, another line of evidence available. In Hovland's study the generalization curve for loudness was much shallower than that for frequency. This is equivalent to saying that generalization to loudness is more extensive. Our results indicate a high degree of generalization to frequency. It is possible, therefore, that the tones we used either were very loud (relative to Hovland's in his pitch study) or else were of differing loudnesses which diminished as the difference in frequency between the test tones and the CS increased. This latter suggestion is not tenable, however. Both experimental groups in the present study gave similar results, though the direction of generalization was opposed; and, since the tones had the same loudness values in each group, a constant factor could not have resulted in the similar patterns. Finally, all the tones elicited GSR's of equal size before conditioning.

We have, of course, no means of deciding whether the tones we used were actually much louder than those in other studies. Unless they were so loud as to mask frequency completely, however, their primary effect could only be the raising of the general response level with little effect upon the shape of the curve. This masking of frequency adequately explains the lack of differences in the first cycle. However, the gradient which appears in later cycles cannot be accounted for on this basis since we should expect these effects to be constant. Some other explanation must be sought.

2. *Degree of conditioning.*—Another possibility is that our subjects were at a level of conditioning not investigated by Hovland. It may be recalled that Hovland tested the degree of generalization after 8, 16, and 24 reinforcements, finding that 16 were optimal. All of his subjects appeared under both conditions in a counterbalanced order, so that half the subjects had already gone through conditioning in each group. The data for each group thus contained the variance attributable to sophisticated subjects. All our subjects were naive. Since previous investigators have emphasized the effect of 'learning to be conditioned' it is quite possible that, while our subjects received the same number of reinforcements as Hovland's, they were not conditioned to the same degree. If, as seems most reasonable, they were not as strongly conditioned, it is possible that the degree of generalization at their level of conditioning is greater than at the points tested by Hovland. There is no evidence to determine the significance of this suggestion and it requires further investigation of the degree of generalization to less than eight reinforcements. It promises to be a fruitful area for investigation.

3. *Statistical treatment.*—This consideration offers the most promising explanation of the differences. There are two factors to be considered here: the result of combining data for different cycles and the error term used in evaluating the obtained differences.

a. *Inter-cycle differences.*—It was mentioned earlier that Hovland (and Bass and Hull) combined the data for

the first two cycles following conditioning and plotted his curves with these grouped data. This assumes the two cycles to be perfectly correlated or else completely independent. Neither assumption seems supportable. In terms of Hull's theory we should expect $_sI_R$ to be operating in cycle II as a result of the reactions in cycle I. The results for these two cycles are, therefore, not combinable. Essentially, this procedure assumes that the effects of reinforcement and extinction on generalization are symmetrical. Since a major source of evidence for such a proposal is drawn from the experiments under consideration, it is necessary to review the problem rather carefully. It is conceivable that the generalization of reinforcement is of equal magnitude at all points, while the generalization of inhibition (due to experimental extinction or 'testing the CR') is in the nature of a negative function. Were this the case, then combining the data for cycle I, which is the only 'pure' test of the generalization of reinforcement, with the results for cycle II, the second extinction trial, would result in a function displaced in the direction of a negative growth curve. Informal inspection of Hovland's data gives some credence to this speculation. If a curve is plotted for the first cycle alone, it appears much shallower than that for the combined data. While this first cycle curve would not have a zero slope, it would lie between such a curve and the distinctly negative one obtained by combining the first and second cycles. In that case it could represent a sampling fluctuation from a zero slope, or conversely, our curve could be a similar variation from a curve of its shape. There can be, at present, no choice between these two alternatives.

Perhaps the major support for this critique comes from Hovland's own work. In reporting his investigation of extinction and spontaneous recovery he says the fact ". . . that on the first trials the generalized responses were larger than the conditioned responses is in conflict with the findings of Pavlov that the initial generalized responses are very small" (14, p. 61). On the second cycle this situation was reversed. While vibratory stimuli were used in this part of his investigation of generalization the results are consonant with ours (and with some of our informal observations noted above). It would then appear that the generalization of inhibition may be very marked, that it operates rapidly in reducing the magnitude of generalized reactions, and that its course may be different from that of the generalization of reinforcement. Additional verification of our results come from an investigation by Hake, Grant and Hornseth (9). They report that two experimental groups ". . . have a greater magnitude of response to the next lower test stimulus than to the positive stimulus itself." These latter results also do not include any effects which could be attributed to an inhibitory process.

b. *Error terms.*—In the formula used by Hovland to compare his groups, the variances for cycles and for individuals per tone were not removed, a relatively large degree of error remaining. This error is in the nature of a correlation existing between cycles. Since the same correlation could be assumed to function in both groups, a lack of inter-group differences might well be the result, the correlation tending to reduce the size of the differences.

On the other hand, the existence of a negative correlation between cycles I and II for each tone in terms of its

removal from the CS would, if not subtracted from the error terms, result in a reduced error term and thus in an over-estimation of the magnitude of the differences obtaining between tones. An analysis, therefore, which contains unrecognized error factors, in addition to those attributable to the experimental variables, would result in inaccurate estimates of differences. We believe that our own analysis has successfully handled these problems.

In view of the various considerations raised it is difficult to specify any simple set of relations between our study and Hovland's. On the one hand we confirm the existence of the generalization of reinforcement and inhibition. On the other hand our results indicate that the forms of the reinforcement and inhibition curves differ. We feel sure that these differences will be reconciled by future research. In any event, however, it would seem undesirable to attempt curve-fitting or extrapolation to other modes of behavior until a better defined function is obtained.

B. *General comments.*—The major import of this study lies in the procedural and analytic portions. Our results are somewhat tentative and their greatest importance is in pointing up the large variability which the phenomena of generalization seem to possess. However, let us consider some theoretical implications. Currently, there are two dominant, opposing views of generalization, and recognition of this state of affairs may help reconcile apparent differences. Studies such as Hovland's, Humphrey's, and the present one are on a non-analytic level of description which is primarily concerned with the shape of the curve of generalization and the way in which later learning is affected. There is little concern for the specific mechanisms involved, and consequently the approach deals primarily with the performance or achievement aspect of the problem.

In contrast there is the approach taken by Lashley and Wade (19), who question both the definition of generalization and the very existence of the phenomenon. Their critique is based on premises which in certain respects result in 'outconditioning the conditioners,' by insisting on the primacy of pairing, differential reinforcement, and the need for some contiguity factor. In essence, they propose that before we can speak of the effects one behavior function may have upon another, there must be shown some way in which they interact. They suggest further that this interaction must be on the basis of some direct comparison procedure. Thus, these workers have recognized the need for further elaboration of generalization as a phenomenon and are primarily concerned with certain of the conditions which may be said to bring it about. On the other hand their objection to the manner of the present research is a question-begging procedure. After formulating their own definition of generalization, they observe that the classical (Pavlovian-type) investigators have not followed the procedures demanded by such a definition; they then reject the results of these experiments as spurious. It is quite evident that other investigators have not followed the procedures demanded by the Lashley and Wade definition. However, the Pavlovian variables and procedures have been shown to be related to behavior in determinate ways and a *phenomenon* can hardly be rejected. The argument at this point is thus seen to lie on a logical and semantic level rather than on an empirical one, and, unless a common meeting ground is established, there can scarcely be any justifiable conflict. The Lashley and Wade paper, while raising clearly fertile problems, has also fabricated the question of which phenomenon should rightly receive a certain name.

But there still remains the problem of whether Lashley and Wade have not raised an exceedingly embarrassing point. There are two sets of empirical data which should be considered. The recent study by Grandine and Harlow (7a), which meets fairly well the conditions

laid down by Lashley and Wade, demonstrates rather clearly that training on a single stimulus will affect responses to other stimuli. Such 'transfer' may evidently be the basis for future changes in behavior. In addition to insisting that generalization rests upon some sort of comparison, Lashley and Wade suggest that Pavlovian generalization is really confusion or lack of discrimination. Here they appear to be on firmer grounds for reaction specificity undoubtedly increases directly with the degree of training; in classical conditioning this is the phenomenon of *discrimination* (11). In accepting such a criticism, however, there is no need to commit oneself to a deduction made by Lashley and Wade, that Pavlovian generalization can thus be of little importance in learning. There is every reason to believe that it is precisely this failure of discrimination which is responsible for the plasticity of behavior and that, in contrast, the generalization of which Lashley and Wade speak is really a rather unusual event. It appears to be closely related to the process of inductive reasoning which, unfortunately, seldom appears in everyday life. As a matter of fact, the Lashley and Wade type of generalization probably occurs only under the most formal auspices. So that, while Lashley and Wade have raised several pertinent questions, we find that on the one hand the weight of evidence is against them and that, on the other, the definition they propose is of a phenomenon which is very severely limited in its operation.

A more fruitful approach appears to be that by Gibson (7), who clearly recognized the dual nature of the problem. Her investigation gives distinct hope to those interested in working out the 'causal' mechanisms of generalization and also the way in which generalization affects other behavior.

VIII. Summary and Conclusions

This study originated in an attempt to verify the form of the generalization function obtained by Hovland in a series of extensive experiments.

1. Twenty-two subjects were conditioned to a tone with shock as the UCS and the GSR as the response. They were then tested for generalization of conditioning to three other tones.

2. All subjects showed conditioning and generalization.

3. The form of the curves obtained was much shallower than that gotten by Hovland and suggested the possibility of a zero slope.

4. Differences are attributed to technique and methods of analysis.

5. It was suggested that the generalization of inhibition follows a different path from that of reinforcement.

6. It is suggested that, since the form of the curve is still questionable, further research is warranted.

7. Finally, a discussion of the Lashley-Wade critique of Hull made the point that there are at least two problems and that no common ground exists for dispute.

(Manuscript received January 11, 1949)

References

1. Bass, M. J., & Hull, C. L. The irradiation of a tactile conditioned reflex in man. *J. comp. Psychol.*, 1934, 17, 47–65.
2. Cook, S. W., & Harris, R. E. The verbal conditioning of the galvanic skin reflex. *J. exp. Psychol.*, 1937, 21, 202–210.
3. Darrow, C. W. The equation of the galvanic skin reflex curve. I. The dynamics of reaction in relation to excitation background. *J. gen. Psychol.*, 1937, 16, 285–309.
4. Davis, R. C. Factors affecting the galvanic reflex. *Arch. Psychol.*, N. Y., 1930, 115, Pp. 64.
5. Davis, R. C. *Ability in social and racial classes: some physiological correlates.* New York: The Century Co., 1932.
6. Davis, R. C., & Porter, J. M., Jr. A measuring device for the galvanic reflex. *J. gen Psychol.*, 1931, 5, 115–120.
7. Gibson, E. J. Intra-list generalization as a factor in verbal learning. *J. exp. Psychol.*, 1942, 30, 185–200.

7a. Grandine, Lois, & Harlow, H. F. Generalization of the characteristics of a single learned stimulus by monkeys. *J. comp. physiol. Psychol.*, 1948, **41**, 327–338.
8. Haggard, E. A. Experimental studies in affective processes. II. On the quantification and evaluation of 'measured' changes in skin resistance. *J. exp. Psychol.*, 1945, **35**, 46–56.
9. Hake, H. W., Grant, D. A., & Hornseth, J. P. Generalization and discrimination in the conditioned eyelid response to sound stimuli. (Read at the Midwestern Psychological Association, May, 1948.)
10. Hilgard, E. R., & Humphreys, L. G. The effect of supporting and antagonistic voluntary instructions on conditioned discrimination. *J. exp. Psychol.*, 1938, **22**, 291–304.
11. Hilgard, E. R., & Marquis, D. G. *Conditioning and learning.* New York: D. Appleton-Century, 1940.
12. Hovland, C. I. The generalization of conditioned responses: I. The sensory generalization of conditioned responses with varying frequencies of tone. *J. gen. Psychol.*, 1937, **17**, 125–148.
13. Hovland, C. I. The generalization of conditioned responses: II. The sensory generalization of conditioned responses with varying intensities of tone. *J. gen. Psychol.*, 1937, **51**, 279–291.
14. Hovland, C. I. The generalization of conditioned responses: III. Extinction, spontaneous recovery, and disinhibition of conditioned and generalized responses. *J. exp. Psychol.*, 1937, **21**, 47–62.
15. Hovland, C. I. The generalization of conditioned responses: IV. The effects of varying amounts of reinforcement upon the degree of generalization of conditioned responses. *J. exp. Psychol.*, 1937, **21**, 261–276.
16. Hull, C. L. *Principles of behavior: an introduction to behavior theory.* New York: D. Appleton-Century, 1943.
17. Hull, C. L. The problem of primary stimulus generalization. *Psychol. Rev.*, 1947, **54**, 120–134.
18. Humphreys, L. G. Generalization as a function of method of reinforcement. *J. exp. Psychol.*, 1939, **25**, 361–372.
19. Lashley, K. S., & Wade, M. The Pavlovian theory of generalization. *Psychol. Rev.*, 1946, **53**, 72–87.
20. Lindquist, E. F. *Statistical analysis in educational research.* Boston: Houghton Mifflin Co., 1940.
21. McGeoch, J. A. *The psychology of human learning: an introduction.* New York: Longman, Green & Co., 1942.
22. Miller, J., & Cole, Luella E. The influence of a "voluntary" reaction upon the development and the extinction of the conditioned eyelid reaction. *J. gen. Psychol.*, 1936, **48**, 405–440.
23. Mowrer, O. H. Preparatory set (expectancy)—a determinant in motivation and learning. *Psychol. Rev.*, 1938, **45**, 62–91.
24. Schlosberg, H., & Solomon, R. L. Latency of response in a choice discrimination. *J. exp. Psychol.*, 1943, **33**, 22–39.
25. Spence, K. W. The differential response in animals to stimuli varying within a single dimension. *Psychol. Rev.*, 1937, **44**, 430–444.
26. Stevens, S. S., & Davis, H. *Hearing: its psychology and physiology.* New York: John Wiley, 1938.
27. Wickens, D. D. A study of voluntary and involuntary finger conditioning. *J. exp. Psychol.*, 1939, **25**, 127–140.

REACTIVE INHIBITION AS A FACTOR IN MAZE LEARNING: II. THE ROLE OF REACTIVE INHIBITION IN STUDIES OF PLACE LEARNING VERSUS RESPONSE LEANING [1]

BY MERRELL E. THOMPSON AND JEAN P. THOMPSON

New Mexico State College

I. Introduction and Statement of the Problem

In one of a recent series of studies by Tolman, Ritchie and Kalish (6) on spatial learning, an experiment was designed to test place versus response learning, the purpose of which was to present *direct* evidence for the hypothesis "that what is learned in T-mazes where choices must be made is *not* a disposition to make certain responses (e.g., right turns) but rather a disposition to orient towards, or go towards the location of the goal." To do this they trained two groups of rats on a single unit maze in which the starting path led into the choice point sometimes from the east and sometimes from the west. The response group, consisting of eight animals, was required to learn to always turn right. The place group, consisting of eight animals, was required to learn to always go to the same place, half of the time turning right and half of the time turning left. Only three rats in the response group reached the criterion (10 successive errorless runs) while the rest developed consistent habits of going always to the same place. The median number of trials to reach the criterion was 72 for this group. All of the rats in the place group reached the criterion within eight trials or less, the median number being two. They concluded that, in situations where there are marked extra-maze cues, place learning is simpler than response learning.

More recently, Blodgett and McCutchan (1), in another study of spatial learning, drew attention to the first of two major weaknesses in the above mentioned experiment: the failure to separate turning disposition and place disposition. This assertion was supported by the fact that discriminable place features were present in each of the two pairs of T arrangements presented for learning, making possible the conclusions that the so-called response group may have learned two place dispositions, each having distinct space supports, and the so-called place group, two turning dispositions.

The other major weakness involved their failure to consider the effect of various time intervals between trials upon rate of learning. This effect is the central problem of the present study. We believe that the results reported by Tolman, Ritchie and Kalish can more adequately be explained in terms not only of unequal variability of cues or space supports for the two groups, but also unequal amounts of reactive inhibition for the two groups.

The principle of reactive inhibition was observed in conditioning studies by Pavlov who stated that "the development of inhibition in the case of conditioned reflexes which remain without reinforcement must be considered only as a special instance of a

[1] A preliminary report of Experiment II of this material was presented by the senior author at the 1948 meeting of the Western Psychological Association, while a report on both Experiments I and II was given by the junior author at the 1949 meeting of the Rocky Mountain Branch of the APA.

more general case, since a state of inhibition can develop also when the conditioned reflexes are reinforced" (5, pp. 234–248). In his recent book (4), Hull has made use of this principle in the explanation of various conditioning phenomena. He assumes that each reaction of an organism builds up a state of negative motivation within the organism which tends to prevent the repetition of that response for a short time. This state of negative motivation is temporary in character, most of it showing spontaneous dissipation after a period of time. Applied to maze behavior, this means that when an animal makes a choice in a maze (e.g., the right alley) and receives an appropriate reward, two things occur. First, the act of turning right is strengthened (principle of reinforcement), and second, inhibition against turning right again for some time is developed. If the next trial follows immediately the animal will tend to alternate his response, that is, turn left at the choice point.

The experimental method of Tolman, Ritchie and Kalish was such that reactive inhibition, which was not allowed to dissipate between massed trials, interfered with the learning of the response group and favored the learning of the place group.

The purpose of the present study was to repeat the study of Tolman, Ritchie and Kalish with slight modifications in order more adequately to control these two variables and thus present a more accurate picture of the relative simplicity of the two types of learning, and particularly to point out the effect of varying the time interval between trials, and so the amount of reactive inhibition in such studies.

II. Apparatus

The maze employed in both experiments (see Fig. 1) was identical with the one used by Tolman, Ritchie and Kalish. It was a single choice-point maze constructed of pine paths two in. wide, painted gray and elevated 30 in. from the floor. The center path extending from the food box F_1 to the food box F_2 was eight feet long, while the paths S_1C and S_2C were each two feet long. A movable barrier four by six in. was used to block the starting paths S_1 and S_2 at C when the opposite path was being used. On the center path F_1F_2 four in. in front of each food box were wire frames from which black curtains eight in. square were suspended. The food boxes at F_1 and F_2 were six in. high, four in. wide and ten in. deep. In each food box was a glass

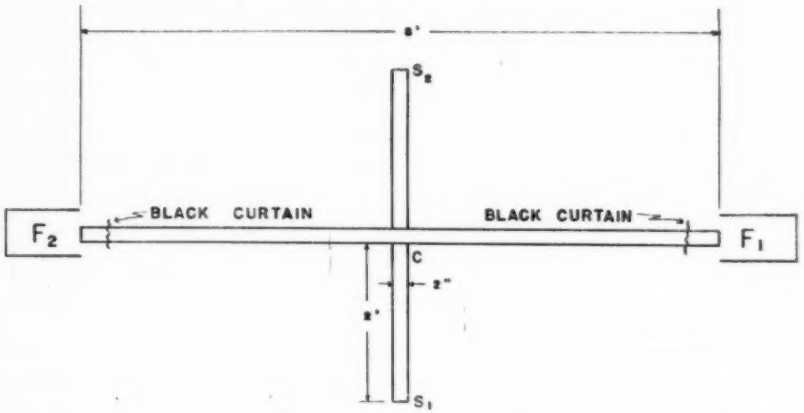


Fig. 1. Floor plan of the maze

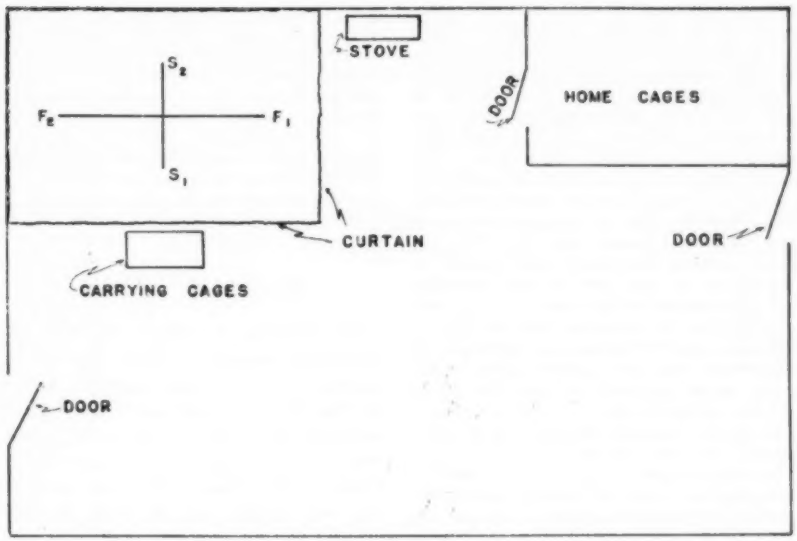


FIG. 2. Room in which maze shown in Fig. 1 was located for experiments I and II

coaster in which the food reward (Purina Rabbit Pellet) was placed.

The maze was set in one corner of a room (see Fig. 2) 20 by 30 feet, and surrounded by a curtain of opaque black material extending from 12 in. below the level of the maze to 28 in. above it. The only illumination in the experiment came from two overhead lamps suspended directly above each food box. The carrying cage was kept outside the black curtain directly behind S_1. The home cages of the rat colony were housed in a temporary enclosure 10 feet from F_1. While the door to this room was kept closed it did not prevent the rats in the home cages from serving as olfactory and auditory extra-maze cues. A gas stove was located one foot beyond the corner formed by the curtains back of S_2 and F_1.

III. SUBJECTS

The subjects consisted of 30 male and female albino rats from the colony maintained by the psychology department of the New Mexico State College. At the beginning of the experiment they were between 80 and 150 days old.

IV. EXPERIMENTAL PROCEDURE

The *S*s were assigned by random numbers to one of the four groups, place massed, place distributed, response massed and response distributed, in such a way that the number of each sex was kept approximately equal. All animals were then given the same preliminanry training.

Preliminary training.—On the first day each animal was allowed to feed for five min. in each of the two food boxes. Next, each rat was placed in the middle of the F_1F_2 path and allowed to run to one of the two food boxes. Following this each rat was given four runs to the food boxes from S_1, the first two of which were free runs, and the third and fourth being forced when necessary in order to give equal experience on each of the two paths, CF_1 and CF_2.

On the third day the rats were given one test trial to determine their position habits. The procedure of this test trial was as follows: both food boxes were empty of food reward and each rat was started from S_1. The path chosen by each animal in the two place groups was noted, and in the experiment proper the opposite path was always correct. That is, for these animals the food was always found at the opposite end of the maze. For the animals in the two response groups a correct response required a turn opposite to the one made on this test trial.

Learning series.—Following this test trial the experiment proper was begun. The maze illustrated in Fig. 1 was used. Each of the rats was given six daily trials on this maze. The order of their starting positions was $S_1S_2S_2S_1S_1S_2$ on odd days and on even days, $S_2S_1S_1S_2S_2S_1$.

An error was recorded whenever a rat turned and ran 12 in. toward the incorrect food box.

For the response groups, massed and distributed, consisting of eight and seven animals respectively, F_1 contained the reward for all animals with initial left turning preferences when they were started from S_1, while F_2 contained the reward when they were started from S_2. Conversely, for the animals with initial right turning preferences, F_2 contained the reward when they started from S_1, while F_1 contained the reward when they were started from S_2. Thus, all animals in these two groups were required to learn always to turn right (or left, depending upon their position habit) whether started from S_1 or from S_2. In accordance with the findings of Blogdett and McCutchan, who attributed the inferiority of their room response group to the greater spatial opposition of cues, both lights were left on for all trials for these two groups. Trials for the response distributed group were spaced at intervals of 15 min.

For the place groups, massed and distributed, consisting of seven and eight animals respectively, F_1 always contained the reward for all animals with initial left turning preferences irrespective of the starting path employed. F_2 always contained the reward for all animals with initial right turning preferences irrespective of the starting path employed. Thus, all animals in these two groups were required always to turn toward F_1 (or F_2, depending on their position habit), whether started from S_1 or from S_2. The light over the incorrect food box was turned off for each trial of all animals in these two groups. A 15-min. interval was allowed between trials for the place distributed group.

V. Experimental Results

Experiment I (place massed and response massed).—Only one of the animals in the place massed group, and none in the response massed group reached the criterion of 10 successive errorless trials in the 12 days or 72 trials. The slight differences between the two groups can be seen in their

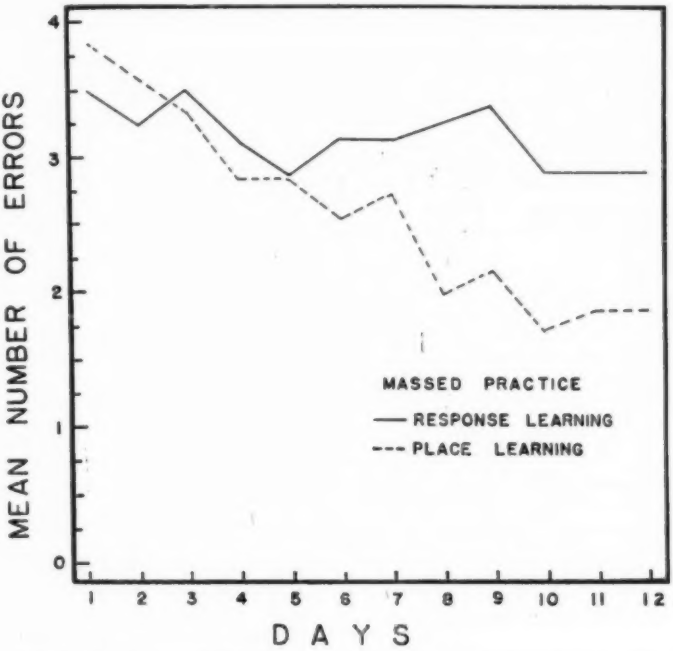


Fig. 3. Mean number of errors per day under conditions of six massed trials per day and marked extra maze cues

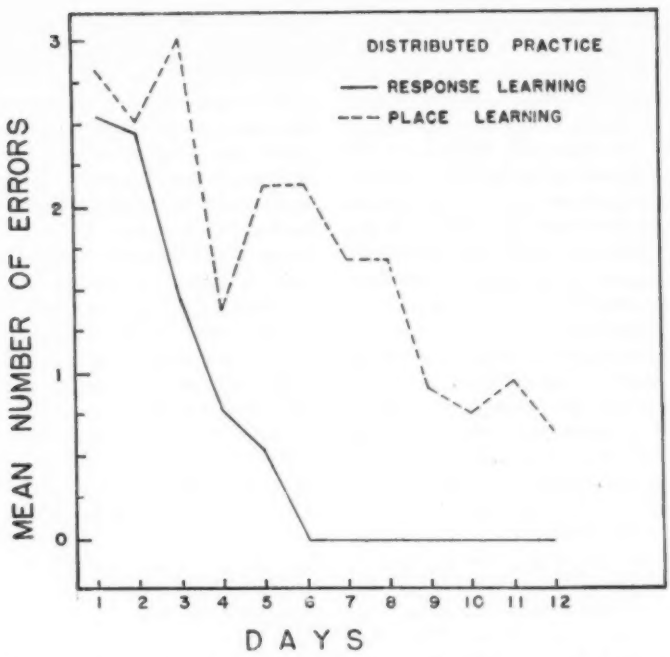


FIG. 4. Mean number of errors per day under conditions of six trials distributed at intervals of 15 minutes and marked extra maze cues

error curves (see Fig. 3). The error curve for the place massed group shows a steady decline while the curve for the response massed group shows practically no decline.

In the statistical analysis of the mean number of errors, the difference of 6.8 was found to be significant at only the 20 percent level of confidence.

Experiment II (place distributed and response distributed).—Three of the eight animals in the place distributed group did not reach the criterion of 10 successive errorless trials in the 12 days or 72 trials. The median number of trials to reach the criterion for this group was 54.5. All of the rats in the response distributed group reached the criterion within 30 trials or less, the median number of trials required being 14.

The differences between the two groups can also be seen in their error curves (see Fig. 4). The error curve for the response distributed group falls rapidly and reaches a plateau at zero on the sixth day. The error curve for the place distributed group, on the other hand, comes down much more slowly and shows greater irregularity.

In the statistical analysis of the errors the difference of 12.7 was found to be significant at beyond the one percent level of confidence.

VI. Discussion

In order to understand the differences in the results of these studies, it will be necessary first to examine more closely the differences in the experi-

mental procedures. The experiment of Tolman, Ritchie and Kalish included massed practice and marked extra-maze cues, while Experiment II of the present study included distributed practice and, aside from the source of illumination for the response group, extra-maze cues marked to an extent *perhaps* less than those of the Tolman, Ritchie and Kalish experiment, but certainly much more than would be employed in the usual controlled experiment in which the rat might be expected to learn a T-maze.

Pertinent to the difference in time interval, and the reactive inhibition which is a function of this variable, is the fact that the animals in the place groups were required to turn LRRLLR on the odd days and RLLRRL on the even days. In the six runs on any given day the animals in the place group were required to repeat an immediately preceding response (turn) only twice. The rest of the time they simply alternated their turning response. On the other hand, the response groups were required to repeat the same turning response on all six trials.

Heather (2) has demonstrated that the alternation of responses is a function of the time interval between trials. This relationship was also found in an analysis of the percent of alternation in the present investigation, which showed that 58.4 percent of the non-criterion trials for the two massed groups were characterized by alternation, while with 15-min. intervals between trials, animals in the distributed groups alternated on only 45.9 percent of the non-criterion trials. In analyzing the first trial of each day and the last trial of the preceding day, the percent of alternation with 24-hour distribution was 42.5 for all four groups.

The reactive inhibition hypothesis, applied to the present problem, enables us to understand why the animals of Tolman, Ritchie and Kalish learned a place more quickly than a response. Since alternation facilitated the learning of the place groups, it can readily be seen that a massed place group would alternate more and so learn more quickly than a distributed place group, and conversely, since alternation interfered with the learning of the response groups, a massed response group would alternate more and so learn more slowly than a distributed response group. In the Tolman study the animals in the response group were required to turn right on every trial. This meant that the inhibition developed on each trial against turning right on the next trial continued to accumulate for the daily session of six trials. This inhibition against repeating the previous response also developed in the rats used in the present response group of Experiment II, but, with 15 min. between trials, this inhibition dissipated, allowing the learning to proceed in the regular manner.

The effect of varying the time interval, with the markedness of extra-maze cues held constant, is shown by a comparison of the curves for the response groups of Experiments I and II of the present study (see Figs. 3 and 4). The difference of the mean errors of these two groups (30.2) is statistically reliable at the 0.1 percent level of confidence. The effect upon the place groups is not so marked. Statistically there is no reliable difference between these two groups.

The other relevant variable, markedness of extra-maze cues, would seem to account for the other differences in the two experiments. Blodgett and McCutchan (1), in their study of spatial learning, ran one group with trials distributed at ten

minute intervals in what they termed "a relatively pure turning disposition" situation, in which no constant extra-maze cues existed. They then ran a place group and response group with the same time interval but in a room with marked extra-maze cues. The differential effect upon response learning of varying the markedness of extra-maze cues, with the time interval between trials held constant, may be seen by comparing the error curves for Blodgett and McCutchan's "pure" or "dome" response group and their room response group. The difference in average total errors for the two groups was statistically significant at the one percent level of confidence for the last half of the learning series. The difference Blodgett and McCutchan attributed to the fact that interference is brought about (for the response groups) by spatial opposition of cues at the choice point (an interference which does not occur in the learning of a simple T-maze, regardless of the disposition acquired). In other words, while the relevant cues remained constant in relation to the goal for the place groups, the animals in the response groups were required to turn toward certain cues 50 percent of the trials, and away from these same cues 50 percent of the trials. Thus, both marked cues and massed trials interfere with response learning.

Tentatively we would assume, in view of the above findings, that there

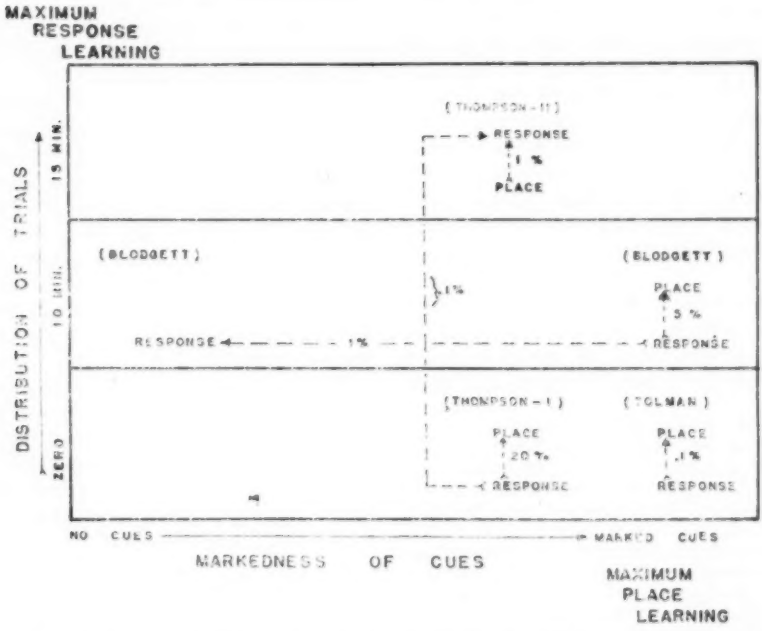


FIG. 5. Framework of possible combinations of variables in experiments testing place versus response learning, together with results of various experiments. Dash arrows point toward superior group with level of significance of difference indicated beside arrow. Figures are based in each case, except the Tolman experiment, upon mean number of errors. The figure in the Tolman experiment was from median number of trials to reach criterion.

exists a hierarchy of combinations of the two relevant variables, extending from the set which most facilitates, to the set which most interferes with the learning of each of the two dispositions, place and response.[2] The rate of learning a place disposition (as defined by Tolman, Ritchie and Kalish) is apparently inversely related to the length of the time interval between trials and directly related to the degree of markedness of cues. On the other hand, the rate of learning a response disposition is directly related to the length of time interval between trials, and inversely related to the degree of markedness of cues. Fig. 5 is an attempt to present this relationship and the results obtained in the above various experiments within the framework of this relationship. It is interesting to note that, of all the differences between the pairs of groups for which we had sufficient data to allow statistical analysis, the difference between the median number of trials to reach the criterion for the Tolman, Ritchie and Kalish place massed group and our response distributed group was the least significant.

Apparently Tolman and his associates, perhaps unintentionally, chose the combination of variables most favorable to place learning and most unfavorable to response learning, and then erroneously attributed their obtained difference to the simple superiority of place learning.

[2] The authors do not mean to imply that they are supporting Tolman, Ritchie and Kalish's assumption and disputing Blodgett and McCutchan's criticism as to what the animals in the above studies have learned, but only wish to stress that whatever the two groups have learned, their rate of learning has depended not only upon the markedness of cues, but also upon trial distribution. It is hoped that these data and interpretation, together with that of Blodgett and McCutchan, will serve to point out that the simple superiority of place learning is not clearly demonstrated and that the experiment of Tolman, Ritchie and Kalish has not excluded any other interpretation, certain recent textbook writers (3, 7) notwithstanding.

VII. Summary

As a check on Tolman's recent conclusion regarding spatial learning, that, "where there are marked extra-maze cues, place learning is simpler than response learning," four experimental groups, place massed, response massed, place distributed and response distributed, were run on a simple T-maze with marked extra-maze cues and under conditions very similar to Tolman's, but with the following variations: (1) the source of illumination was not spatially opposed for the starting positions and choice point of the response groups, and (2) the trials were spaced at 15-min. intervals for the distributed groups.

It was found that with distributed trials response learning was more rapid than (1) place learning with distributed trials, and (2) response learning with massed trials. The difference in mean errors for the two distributed groups was significant at beyond the one percent level of confidence, and for the two response groups was significant at beyond the 0.1 percent level of confidence.

Tolman's experimental method was such that not only spatial opposition of cues but reactive inhibition, a function of time interval between trials and operating to increase alternation, interfered with response learning and facilitated place learning.

(Manuscript received for immediate publication October 11, 1949)

References

1. Blodgett, H. C., & McCutchan, K. Place versus response learning in the simple T-maze. *J. exp. Psychol.*, 1947, 37, 412–422.

2. HEATHER, G. L. The avoidance of repetition of a maze reaction in the rat as a function of the time interval between trials. *J. Psychol.*, 1940, 10, 359–380.
3. HILGARD, E. R. *Theories of learning.* New York: Appleton-Century-Crofts, 1948.
4. HULL, C. L. *Principles of behavior.* New York: Appleton-Century, 1943.
5. PAVLOV, I. P. *Conditioned reflexes* (trans. by G. V. Anrep). London: Oxford Univ. Press, 1927.
6. TOLMAN, E. C., RITCHIE, B. F., & KALISH, D. Studies in spatial learning: II. Place versus response learning. *J. exp. Psychol.*, 1946, 36, 221–229.
7. WOODWORTH, R. S., & MARQUIS, D. G. *Psychology* (fifth ed.). New York: Henry Holt, 1947.

DISCUSSION

COMMENTS ON LITTMAN'S "CONDITIONED GENERALIZATION OF THE GALVANIC SKIN REACTION TO TONES"

BY CARL I. HOVLAND

Yale University

Littman's repetition* of the writer's experiment on tonal generalization represents an important contribution in utilizing some of the improvements in measurement techniques that have come about during the fifteen years since the original study was done. The most significant advance has been the application of scaling techniques to the galvanic skin response. Littman's use of a ratio taking into account the absolute level of resistance as a basis for evaluating change is an improvement over the writer's method. Recent work indicates, however, that even his method has serious limitations as a scale and that more adequate procedures are now available (10). Littman's use of a vacuum tube voltmeter and non-polarizable electrodes constitutes another improvement in technique.

In contrast to the improved procedure for measuring response, Littman's methods of controlling stimuli seem to the writer less adequate than those in the original study. In the writer's experiment a carefully designed sound-proof room was employed, while in Littman's study the room is only described as a "long, rather narrow, high-ceilinged room painted lamp-black." This is not a trivial difference. Not only does the sound-proof room reduce extraneous sounds and thus provide greater constancy of conditions and resultant decreased variability but the noise level directly affects the equating of the tonal stimuli for loudness. Considerable masking resulting from the higher noise level would make both the decibel levels used by the writer and those of Fletcher and Munson used by Littman quite inapplicable. Because of the shape of curves of equal loudness the tones in the middle of the frequency range would be differentially affected from those at the high and low ends. Some suggestion of the operation of this factor in Littman's study is found in the fact that even before conditioning the responses to the end tones (153 and 1967 cycles) averaged 175.5 units while responses to the middle tones (468 and 1000 cycles) averaged 196.5. The difference is not, however, statistically significant.

The experimental results for Group I in Littman's study (conditioned to 153 cycle tone) closely parallel those obtained by the writer. In this study, the first in the series (5), the writer combined the data for successive cycles, not being aware of the differential extinction rates for conditioned and generalized responses because of using only two testing cycles. The differential rate of extinction was, however, emphasized in the second (6) and third (7) papers of the series. It was clearly seen in the second study where three cycles of testing were employed. Results from this study are graphed in Fig. 1. The differential decline is evident on the third cycle. The similarity to the results obtained during the first three cycles in Littman's study is striking.

It is not clear why there is such a divergence in results for Group II (conditioned to 1967 cycles). The extent of the difference between Littman's two groups is somewhat obscured by his use of a weight of 500 added for convenience in coding. If the coding weight of 500 is removed his results are as follows:

	Group I				Group II			
	0	1	2	3	0	1	2	3
First cycle	54	72	57	74	105	117	131	46
Second cycle	64	52	53	37	135	137	117	55

* Present issue of this JOURNAL, pp. 868–882.

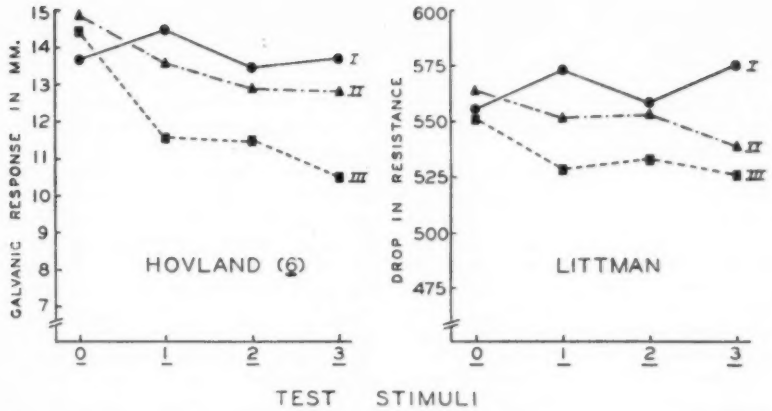


FIG. 1. Magnitude of response to conditioned stimulus (0) and to stimuli progressively more remote (1, 2 and 3), showing progressively greater differentiation on successive testing cycles for Littman's Group I and for second generalization study of writer (6)

The values for his second group are nearly double those for the first group. Sizeable differences were also found before conditioning which Littman attributes to "chance selection factors." In the writer's experiment the two groups were sufficiently similar to permit combining them, thus giving greater regularity to the results. It might be thought that the differences between Littman's groups could be due to the lack of equating of the 153 and 1967 cycle tones (for reasons suggested above). But the results of the writer [analyzed from his original data by Hilgard and Marquis (3)], verified by a number of later studies, indicate that the intensity of the conditioning stimulus used for conditioning is not critical, and Littman's test intensities were of course identical for the two groups.

Littman's results for Group II are also at variance with those of Humphreys (9), who repeated a portion of the writer's experiment, using a 1967 cycle tone as conditioned stimulus. His stimuli were concentrated within 25 j.n.d.'s of the conditioned stimulus but his 1000 cycle test tone was identical with that of Littman and of the writer. His results are presented for comparison with those of Littman and the writer in Fig. 2. In each case the data for the first two cycles are pooled. Comparison is made by expressing the generalized responses as percentages of the response to the conditioned stimulus. The gradient obtained by Humphreys is somewhat steeper than that of the writer; that of Littman flatter in the initial portion and steeper in the most remote portion.

Part of the fairly sizeable discrepancies between the three studies may be due to sampling fluctuations. If some limit of sampling (for example, three standard errors) is used as a radius around each of the experimentally obtained values in any of the three studies it will be found that a straight line, a positively accelerated or a negatively accelerated gradient, or an ogive would all fall within the sampling limits. Further evidence of variability is the fact that although the arithmetic means in the writer's study show a negatively accelerated gradient, as Spence (12) has pointed out the medians show a positive acceleration. Many more determinations at each point and a large number of test points are needed for a precise determination of the gradient under a particular set of experimental conditions. In the only study employing closely spaced stimuli with the galvanic response, that of Humphreys (9) mentioned above, a

negatively accelerated gradient similar to that of the writer was obtained. But a recent study by Hake, Grant and Hornseth (2) on the eyelid response found the generalized responses to closely similar frequencies larger than those to the conditioned frequency.

For further research we are greatly in need of an adequate dimension along which to order our stimuli. Present scales are at best ordinal with no assurance that equal units obtain throughout the dimension. The j.n.d. scale used by the writer is criticized by Littman: "As determined by Hovland they [the tonal frequencies] were 25 JND's apart and presumably establish equal units for a generalization scale. Humphreys has demonstrated the untenability of this proposition, by demonstrating octave effects. Thus the method of equal-appearing intervals would seem better suited to establish 'equal units' within the auditory dimension." With the latter point the writer does not agree. It is perfectly true that a scale of j.n.d.'s is a far from adequate dimension since it does not perfectly correlate throughout the range with a scale of psychological similarity. Thus the widely known octave effect. But the method of equal-appearing intervals does not take care of this point either. If the test stimuli are separated in terms of equal-appearing intervals, units in between may not be equally spaced and may contain inversions, due, for example, to the same octave effects. Hence, interpolation may be unjustified. On the other hand, if the scale is synthesized from successive equal-appearing units, one may just as readily run into octave effects at the test frequencies as with j.n.d. units.

With respect to Littman's other criti-

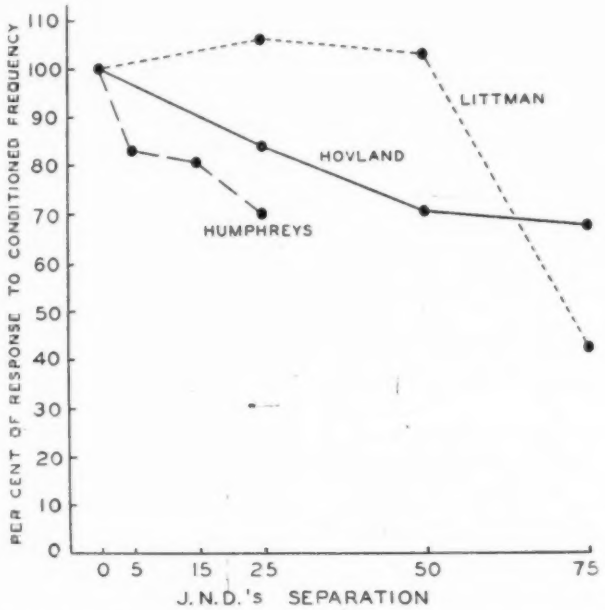


FIG. 2. Comparison of Littman's Group II with corresponding results of the writer (5, subjects XI–XX) and of Humphreys (9), showing response to 1967 cycle conditioned stimulus and to test stimuli differing from 1967 by varying numbers of j.n.d.'s in frequency. Responses on first and second testing cycles combined for each study.

cism, concerning the combining of data from more than one cycle, the writer agrees that it would be better if test responses could be obtained in such a way as to avoid extinction effects. But Littman himself employs the same procedure involving extinction, although in a less easily recognized form. To avoid his criticism, only a single test should be made following conditioning. But in his study four extinction trials were included in each cycle. This permits generalization of extinction from the unreinforced test of one tone to the other tones. If Littman followed out the implication of his criticism he would use only the first test trial following conditioning. He would then have less than three readings for each frequency (11 subjects divided by 4 frequencies). Even in their present form his curves are based on only 11 readings. For the shape of the curve of generalization to be accurately determined for a particular set of conditions it will be necessary to go even further than Littman's suggestion and to employ large groups of subjects given only a single test trial at each test frequency. One further complication must be avoided, viz., adaptation to the conditioned frequency, a phenomenon labelled by the writer "inhibition of reinforcement" (4). In Littman's results, in those of Hake, Grant, and Hornseth (2), and in several generalization studies by the writer (6, p. 286f.; 7, p. 56f.) we find the responses to the conditioned stimulus initially depressed below the generalized responses. In the writer's study on generalization of pitch (5), and in the study by Humphreys (9), however, this phenomenon did not appear. We are still far from a satisfactory understanding of the conditions for the presence or absence of this effect.

With a large number of subjects and a large number of different frequencies each tested only a single time the data will become of sufficient precision to permit analysis of factors affecting the form of generalization curves. Lack of attention to factors influencing the shape of generalization curves has led to references to *the* generalization gradient in much the same way that early students referred to *the* forgetting curve. Factors already uncovered are amounts of reinforcement [Hovland (8), Razran (11)], type of reinforcement pattern [Humphreys (9)], and strength of motivation [Brown (1)]. Investigation of other factors affecting the form of the gradient appears a most promising area for further research.

(Manuscript received July 11, 1949)

References

1. Brown, J. S. The generalization of approach responses as a function of stimulus intensity and strength of motivation. *J. comp. Psychol.*, 1942, **33**, 209–226.
2. Hake, H. W., Grant, D. A., & Hornseth, J. P. Generalization and discrimination in the conditioned eyelid response to sound stimuli. *Amer. Psychologist*, 1948, **3**, 361.
3. Hilgard, E. R., & Marquis, D. G. *Conditioning and learning*. New York: Appleton-Century, 1940.
4. Hovland, C. I. 'Inhibition of reinforcement' and phenomena of experimental extinction. *Proc. nat. Acad. Sci.*, 1936, **22**, 430–433.
5. Hovland, C. I. The generalization of conditioned responses. I. The sensory generalization of conditioned responses with varying frequencies of tone. *J. gen. Psychol.*, 1937, **17**, 125–148.
6. Hovland, C. I. The generalization of conditioned responses. II. The sensory generalization of conditioned responses with varying intensities of tone. *J. genet. Psychol.*, 1937, **51**, 279–291.
7. Hovland, C. I. The generalization of conditioned responses. III. Extinction, spontaneous recovery, and disinhibition of conditioned and of generalized responses. *J. exp. Psychol.*, 1937, **21**, 47–62.
8. Hovland, C. I. The generalization of conditioned responses. IV. The effects of varying amounts of reinforcement upon the degree of generalization of conditioned responses. *J. exp. Psychol.*, 1937, **21**, 261–276.
9. Humphreys, L. G. Generalization as a function of method of reinforcement. *J. exp. Psychol.*, 1939, **25**, 361–372.
10. Lacey, O. L., & Siegel, P. S. An analysis of the unit of measurement of the galvanic skin response. *J. exp. Psychol.*, 1949, **39**, 122–127.

11. RAZRAN, G. H. S. Studies in configurational conditioning. V. Generalization and transposition. *J. genet. Psychol.*, 1940, 56, 3–11.

12. SPENCE, K. W. A reply to Dr. Razran on the transposition of response in discrimination learning. *Psychol. Rev.*, 1939, 46, 88–91.

SOME OBSERVATIONS ON MEYER'S STUDY OF REACTION TIME AND MUSCLE TENSION

BY ROBERT S. DANIEL

University of Missouri

Meyer (6) has recently published the report of a dissertation which was a study of remote muscular tensions (electromyograms in a non-participating body part) paralleling progressive decrease in RT performance. The objective was to check Dunlap's hypothesis of motor tension reduction (4). Since a number of equipment and operational errors seem to be involved in the study, attention is called to a need for reevaluation of the data. The following observations are based upon the article (6), the original thesis (5), and some of the protocols and photographic records from the study (7).[1]

Amplifier.—It is reported that "a high frequency amplifier" was used in the action potential (AP) measurements (6). Bioelectric phenomena from muscle are characteristically *low* in frequency, 20 to 400 cps (1), while being extremely low in voltage. Standard equipment in work of this kind is a *high gain* amplifier capable of passing *low frequencies*. This was merely a misstatement, according to Meyer (7), since the amplifier *was* properly designed.

Shielding and interference.—An electrically shielded room was used, but *within* the shielded space were several pieces of electric and electronic equipment. This apparatus in operation would introduce external transients, which is the very thing the shield should exclude. Efforts were made to eliminate such artifacts, primarily by the introduction of a small capacity condenser across the CRT input. In the writer's opinion, no crucial test of its effectiveness was made.

Camera.—The oscilloscope was photographed by a "35 mm. motion picture camera," with a speed of "10 castellations per sec." (6). The speed is identified as "10 frames per sec." in the thesis (5), but now corrected to mean "10 perforations per sec." (7). The latter checks properly with time relations on the records seen by the writer. The camera was undoubtedly a 35 mm. *moving film* camera (no shutter and continuous film movement), since the record samples show continuous oscilloscope exposure rather than successive stills.

Photographic records.—The two samples of photographic records presented in the article as Fig. 1 are characteristic of the more than 80 records from the study which were inspected for these observations. There are three potentials in each sample identified as follows: A is an imposed signal "beginning 0.2 sec. before the stimulus light"; B is the "action potential at the moment of stimulation"; C is the "action potential at moment of reaction" (6). The validity of potentials B and C may be seriously questioned from several points of view. Arguments which follow develop the point and constitute the major critique of the paper.

1. Consider first the published sample AP record. If, in truth, A precedes the stimulus by 0.2 sec., and B occurs at the moment of stimulation, then we have a time base to measure the delay between the stimulus (B) and potential C which occurs at the "moment of reaction." The RT value obtained (reaction 82) by the most generous measure of A, then

[1] Dr. Meyer has very kindly made this material available to the writer and granted permission for its use in these 'observations.'

applying the time scale to B-C, is 540 ms.—a figure 12 SD's beyond the stated RT mean of daily subject means. Such a RT is possible in a single trial, but is hardly representative. The proper RT here is 395 ms. (7), which must mean that either the fore-period time was 0.146 rather than 0.2 or that the potential B did not occur at the moment of stimulation or that C did not occur at the moment of response (or some combination of the foregoing). Since the same difficulty is found in other samples seen, the statement that the CRT trace "could be related with a high degree of certainty to the action potential from the leg occurring at the time of reaction" (6, p. 99) is hardly accurate.

2. In a number of records the spike singled out for measurement was found by the method described in the preceding paragraph (7). In the majority, however, there was no AP present other than the questioned potential C, which stands out in prominent isolation. It is quite unlike typical APs. The striking feature is its stereotyped form, the following characteristics being invariable from sample to sample; it is (a) a near instantaneous deflection of great amplitude, (b) apparently independent of tension as revealed by typical APs, (c) always of the same polarity, (d) slower in decay than in its rise, (e) terminated by a direct swing of opposite polarity about $\frac{1}{4}$ the amplitude of the initial phase, then a drift back to neutral. It is the kind of potential one would expect to record from opening or closing electric circuits; it is unlike typical APs found on the same records occasionally. Much the same objection can be raised against the validity of potential B, plus more obvious difficulties with the statement that it occurs "at the moment of [visual] stimulation" (6). Although a near stimulus-AP simultaneity is reported by Davis (3), it is different in form and was obtained by stimulation of a tendon reflex.

3. Single isolated diphasic spike potentials are not ordinarily found when surface electrodes are used. Such electrodes pick up and summate in random fashion the spike potentials from several motor units within the muscle. Davis (2) has shown the pattern of such remote muscle potentials to be *wave trains* during simple voluntary hand thrust not unlike Meyer's *Ss* used. The peak amplitude of such perseverating potentials is reached gradually and even at one second following stimulation it has decayed to only 70 percent of peak amplitude in remote arms and 35 percent in remote legs (2, Fig. 5). The isolated spikes making up much of Meyer's data are so different as to suggest a non-physiological basis.

4. In one of the records inspected the camera was allowed to run continuously for several trials, instead of being turned off shortly after the response. The record is typical in every respect save that in every trial it also shows a fourth potential (see Fig. 1), which we shall call D, falling about 2.5 seconds after C. It is similar to C except that it has reversed polarity. What is its source? We note that "the stimulus light remained on until the RT had been recorded" (6, p. 101). A physiological basis for it is less reasonable.

The arguments above leave one with the necessity of considering the possibility that the fundamental data of the study are not muscle action potentials at all, but are transients initiated by the RT equipment. The study deserves repetition under conditions of less severe

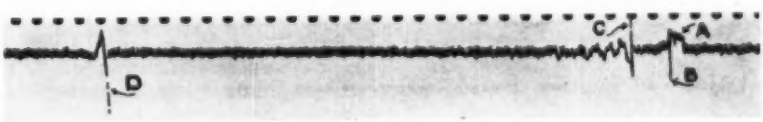


FIG. 1. Reproduction of a typical photographic record from the Meyer study; protocol 49. Potentials A, B, and C are identified as in the original. Very slight typical APs, 60-cycle interference, and the unidentified potential D are also shown.

restrictions on equipment and supplies, and with better control against artifacts.

(Manuscript received June 20, 1949)

REFERENCES

1. DAVIS, R. C. Methods of measuring muscular tension. *Psychol. Bull.*, 1942, **39**, 329–346.
2. DAVIS, R. C. The pattern of muscular action in simple voluntary movements. *J. exp. Psychol.*, 1942, **31**, 347–366.
3. DAVIS, R. C. The pattern of response in a tendon reflex. *J. exp. Psychol.*, 1942, **30**, 452–463.
4. DUNLAP, K. *Elements of psychology*. St. Louis: Mosby, 1936.
5. MEYER, H. D. Reaction time as related to tensions in muscles not essential in the reaction. Ph.D. Thesis, Univ. Calif., 1946.
6. MEYER, H. D. Reaction time as related to tensions in muscles not essential in the reaction. *J. exp. Psychol.*, 1949, **39**, 96–113.
7. MEYER, H. D. Personal correspondence.

SOME REMARKS CONCERNING DANIEL'S OBSERVATIONS

BY HENRY D. MEYER

Stevenson, Jordan & Harrison, Inc.

Daniel (1) has brought forth a number of criticisms of Meyer's reaction time and muscle tension study (4). In order to clarify the basic facts of experimental procedure and to answer Daniel's criticisms, the following remarks are presented. The headings and sub-headings used correspond to the headings used by Daniel (1).

Amplifier.—It was designed to pass a range of frequencies from 20 to 1000 cps at not greater than 2 microvolts random noise level in this range.[1] Relative to bioelectric phenomenon this is a high frequency amplifier. In a non-bioelectric context it is not.

Shielding and interference.—The shielding of the experimental room was effective in eliminating interference from transients external to the room since none appeared in the records. The controls against interference from the electrical circuits of the experimental apparatus as the source of the wave forms recorded in the study (4, p. 101) were as follows:

1. The subject pressed on a rubber pad instead of the reaction key with the chronoscope circuit open at one sitting, closed at another. This produced records free from chronoscope circuit interference.

2. The stimulus lamp was left on until the reaction had been completed for the majority of subjects but turned off before the reaction occurred for two subjects. This produced records free from stimulus lamp circuit interference.

3. A 25,000 ohm resistance was placed between the electrodes and the various apparatus circuits were activated by the *E*. This produced no observable change in the record.

The wave forms produced by pressing on the rubber pad were spiked in pattern and did not consist of random single deflections as muscle action potentials (MAP's) frequently do. While these wave forms were not as instantaneous in onset as most of the records obtained during the study, the differences are not clear-cut. The slight differences which do appear may depend on differences in the action required for pressing a rubber pad as compared to a telegraph key.

Daniel seems to be assuming too much when he implies that the remote AP's of Meyer's study should be similar in appearance and timing to those in the study by Davis (2). Was Davis' study one involving maximal speed of response to a signal following a period of prepara-

[1] Dr. G. E. Mount of the U.C.L.A. Psychology and Engineering staff has very kindly considered the technical aspects of this controversy and supplied the author with additional information concerning the characteristics of the amplifier used in the study.

tory tension? If not, the studies do not have much, if anything, in common.

Control three did not, as Meyer believed at the time, preclude the possibility of interference pick-up by the subject. Therefore, this control does not eliminate the possibility that electrostatic pick-up occurred.

Concerning potentials B and D it should be clear from the study itself that Meyer never claimed any controls for their validity as MAP's (4, p. 110). Meyer's hypothesis concerning potential B's validity as an MAP stemmed from an over-enthusiastic acceptance of the response hypothesis of Dunlap (3). However, it had no weight in determining the character of either the results or the conclusions of the experiment.

The camera.—As was previously stated (4, p. 99) the exposure of the film was continuous. The term castellations was based on the fact that the perforations on the film give it the appearance of a castle turret. The term was not original with Meyer, but came from a local source and may not be in general use. In any case the reference to the speed of the film could not be ambiguous, since it was used only in a descriptive manner and had no relation to the interpretation of the article or its significance.

Photographic records.—Under this heading fall Daniel's major criticisms relating to the crucial issue of validity.

1. Daniel seems never to have come to a clear understanding of the time indicators on the film records. His original confusion was based upon taking the input signal period A-B to be exactly .2 sec. and using it as a time standard. This was not done by Meyer and should not be expected to work as a method of analysis. As is apparent from the films which Daniel studied, this time varied. (Measured by the 60-cycle 'pips' in the base line it varies from .05 to .2 sec.) The variations corresponded to variations in the rate of turning of the commutator which introduced and removed this signal. All film time measurements were based on the interval between pots. B and C using the number of film perforations as the indicator. Using this method, Meyer has again tested the agreement between the film and chronoscope measures of RT for the reaction sample used in the article illustration (1, p. 110) and for a random sample of the data. The differences are within a few msec. and probably depend on the fact that the two methods of measurement are distinctly different.

A completely unequivocal time line on the film record is found in the 60-cycle base line which occurs in the figure Daniel uses as an illustration (1). 'Using this more refined measure we find 11 cycles elapsed between B and C, or 182 msec. The chronoscope RT for this sample was 185 msec. Using film perforations, we find one and five-sixths perforations or 183 msec.

2. A recent review of the data by Meyer leaves him in disagreement with most of Daniel's points in this paragraph. Potential C is quite variable in amplitude, duration and pattern during recovery for different subjects. Rather than being isolated, it often occurs in the middle of a series of other spikes and smaller deflections which are undoubtedly MAP's.

(a) Potential C does commonly show an instantaneous deflection which is shown in Daniel's illustration by the arrow from C. However, this is not invariable and also occurs with other more obviously valid MAP's when their amplitude is high. The instantaneous deflection could occur as a very rapid spatial summation of MAP's related to the type of maximal speed response from which the data were obtained.

(b) It is questionable whether potential C was independent of the more typical MAP's inasmuch as there was a characteristic decline in both types of potentials from the first to the last records in a single day's trial whenever the more typical MAP's were present.

(c) Since the potentials come from the same electrode source, whether of muscular or external origin, there is no reason why the polarity should change or that lack of change should be relevant to the problem.

(d) There is a characteristic distortion

of high gain condensor-coupled amplifiers[2] which results in a dip in the reverse direction and a slow drift to recovery following a 'spike' input potential.

(e) This is not a change in the polarity of the potential and potential C is, therefore, not diphasic. This dip and change in direction are produced by the amplifier and not the source at the electrodes (5). It is true that potential C is similar in appearance to a record that would be obtained from opening or closing an electric circuit. This however, does not prove that potential C is from such a source or that the source could not equally well be muscle action in the calf of the leg at the moment of reaction.

3 and 4. These points have already been covered in the preceding discussion.

Conclusion.—There is no way to verify logically the implication of Daniel's statement that potential C does not look like a typical MAP. Sufficient basis is present to expect the potential used in this study to be atypical. Although it can be agreed that it appears similar in many cases to what would be produced by the losing or opening of a circuit, this similarity of appearances would occur for records of the degree of resolution available for the study. Such a similarity is hardly the basis for a discussion. The data of Meyer's study, as is the case for other initial studies, will have to wait until further research confirms or rejects them.

[2] Such amplifiers are almost invariably used in studies of action potentials.

(Manuscript received August 26, 1949)

References

1. Daniel, R. S. Some observations on Meyer's study of reaction time and muscle tension. *J. exp. Psychol.*, 1949, **39**, 896–898.
2. Davis, R. C. The pattern of muscular action in a simple voluntary movement. *J. exp. Psychol.*, 1942, **31**, 347–366.
3. Dunlap, K. *Elements of psychology*. St. Louis: Mosby, 1936.
4. Meyer, H. D. Reaction time as related to tensions in muscles not essential in the reaction. *J. exp. Psychol.*, 1949, **39**, 96–113.
5. Mount, G. E. Personal correspondence.

AMERICAN PSYCHOLOGICAL ASSOCIATION

1515 Massachusetts Avenue, N.W.
Washington 5, D. C.

The American Psychological Association, founded in 1892 and incorporated in 1925, is the major psychological organization in the United States. With approximately 6,700 members and 2,000 affiliates, it includes most of the qualified psychologists in the country. The purpose of the APA is to advance psychology as a science, as a profession, and as a means of promoting human welfare. It attempts to further these objectives by holding annual meetings, publishing psychological journals, conducting a personnel placement service for psychologists, and working toward improved standards for psychological training and service.

In order to give recognition to the specialized interests of different psychologists, the APA includes seventeen Divisions. Any person, after becoming a member of the APA may apply for membership in as many Divisions as he wishes. The Divisions are:

Division of General Psychology
Division on the Teaching of Psychology
Division of Experimental Psychology
Division on Evaluation and Measurement
Division on Childhood and Adolescence
Division of Personality and Social Psychology
The Society for the Psychological Study of Social Issues—a Division of the American Psychological Association
Division on Esthetics
Division of Clinical and Abnormal Psychology
Division of Consulting Psychology
Division of Industrial and Business Psychology
Division of Educational Psychology
Division of School Psychologists
Division of Counseling and Guidance Psychologists
Division of Psychologists in Public Service
Division of Military Psychology
Division on Maturity and Old Age

Each Division has its own officers. Each meets annually at the time and place of the APA meeting. Each has its own membership requirements, which in some cases are higher or more specialized than the requirements for election to the APA.

The annual meetings of the APA are held in September. An attempt is made to choose meeting sites in such a way that attendance will be convenient for members and their guests in different sections of the country at different times. Thus, the 1950 meeting will be held on September 4 to 11 at Pennsylvania State College, and the 1951 meeting in Chicago. These meetings provide the members with an opportunity to present or hear reports of psychological research and lectures on topics of psychological interest, and to participate in formal and informal discussion groups. The research reports, lectures, and discussion groups cover varied topics of current interest within the field of psychology.

The chief governing body of the APA is the Council of Representatives. It includes representatives from each of the Divisions. A Board of Directors, composed of the four officers of the APA (President, President-elect, Recording Secretary, and Treasurer) and six Council members elected by the Council, is the administrative agent of the Council and exercises general supervision over the affairs of the Association.

The APA maintains an office in Washington which acts as a coordinating center for all APA activities. Journal subscriptions, membership applications, personnel placement requests, and general APA business procedures are handled in this office.

POPULAR REPRINTS AND ARTICLES

American Psychological Association

1515 Massachusetts Ave. N.W., Washington 5, D.C.

Johnny Rocco, by Jean Evans. From the *Journal of Abnormal and Social Psychology,* July, 1948. One for 25¢; 50 for $10.00.

A New Readability Yardstick, by Rudolf Flesch. From the *Journal of Applied Psychology,* June, 1948. One for 25¢; 50 for $5.00.

Tables for Use with the Flesch Readability Formulas, by J. N. Farr and James J. Jenkins. From the *Journal of Applied Psychology,* June, 1949. One for 25¢; 50 for $10.00.

Standards for Appraising Psychological Research, by Dael Wolfle, Rensis Likert, Donald G. Marquis, and Robert R. Sears. From the *American Psychologist,* August, 1949. One for 10¢; no reduction for quantity orders.

JOURNAL OF EXPERIMENTAL PSYCHOLOGY

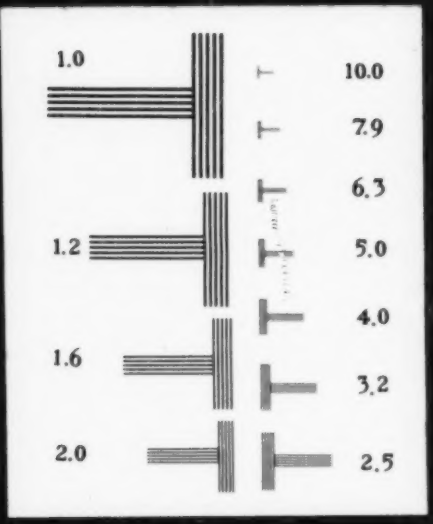
VOL.
NO.

1950

PUB. 276

UNIVERSITY MICROFILMS
ANN ARBOR, MICHIGAN. 1951

RESOLUTION CHART



100 MILLIMETERS

INSTRUCTIONS Resolution is expressed in terms of the lines per millimeter recorded by a particular film under specified conditions. Numerals in chart indicate the number of lines per millimeter in adjacent "T-shaped" groupings.

In microfilming, it is necessary to determine the reduction ratio and multiply the number of lines in the chart by this value to find the number of lines recorded by the film. As an aid in determining the reduction ratio, the line above is 100 millimeters in length. Measuring this line in the film image and dividing the length into 100 gives the reduction ratio. Example: the line is 20 mm. long in the film image, and $100/20 = 5$.

Examine "T-shaped" line groupings in the film with microscope, and note the number adjacent to finest lines recorded sharply and distinctly. Multiply this number by the reduction factor to obtain resolving power in lines per millimeter. Example: 7.9 group of lines is clearly recorded while lines in the 10.0 group are not distinctly separated. Reduction ratio is 5, and $7.9 \times 5 = 39.5$ lines per millimeter recorded satisfactorily. $10.0 \times 5 = 50$ lines per millimeter which are not recorded satisfactorily. Under the particular conditions, maximum resolution is between 39.5 and 50 lines per millimeter.

Resolution, as measured on the film, is a test of the entire photographic system, including lens, exposure, processing, and other factors. These rarely utilize maximum resolution of the film. Vibrations during exposure, lack of critical focus, and exposures yielding very dense negatives are to be avoided.

THIS PUBLICATION IS REPRO-
DUCED BY AGREEMENT WITH THE
COPYRIGHT OWNER. EXTENSIVE
DUPLICATION OR RESALE WITH-
OUT PERMISSION IS PROHIBITED.